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Our Forestry Problems as Seen by Hillebrand in 1856.

Elsewhere in this issue of the *Record* is reprinted a paper read before the Royal Hawaiian Agricultural Society at its sixth annual meeting by Dr. Wm. Hillebrand. This meeting took place in 1856, but the salient points of Dr. Hillebrand's making, apply with extraordinary accuracy to the matter of forestry in relation to agriculture, as the subject confronts Hawaii today.

Dr. Hillebrand at that time said with unmistakable significance, "As long ago as 1804, Alex. von Humboldt * * * warned that the waste of forests entailed two evils on the following generation: a want of fuel, and a deficiency of water. The reality of the first is self-evident; the second * * * a statement which, if substantiated entailed important consequences, was well worthy to arouse a general attention. * * * Such a mass of evidence has been accumulated that the theory may well be said to have been converted into a doctrine."

Proceeding by way of an unusually interesting exposition of "the influence of forests upon the absolute quantity of rain or precipitate of atmospheric moisture," Dr. Hillebrand offered illustrations convincingly definite, and covering an enormous field.

Of local conditions he spoke freely. "It cannot be denied," he said, "that in many places the domain of the forest has been seriously encroached upon by man, and more by cattle." The paper invites quotation, and repays reading. It is something to know that so early as 1856 attention was being called to the "startling fact" that "the whole plateau of Waimea in Hawaii has been spoliated entirely of its original forest which only twenty-five years ago formed an impenetrable thicket, by the agency of wild cattle."

"Of all the destroying influences man brings to bear on nature," said Dr. Hillebrand some sixty-odd years ago, "cattle is the worst."

Certain parts of these Islands offer no less substantial testimony to the truth of that dictum now than then.

It appears toward the last of the paper that Dr. Hillebrand was sanguine of local reforestation. "Nowhere, I imagine, shall we have to wait more than six to eight years before some results are obtained. * * * It is my opinion that on the banks of rivers, and in low, wet places our end may be attained in less than

four years." He spoke of results in his Honolulu garden where some introduced species grew in little more than one year to a height of twenty-four feet, and others ten and sixteen feet.

It is interesting that the Hawaiian Sugar Planters' Association has established a tree nursery adjoining the Hillebrand garden, and through the courtesy of Mrs. Mary E. Foster is now utilizing seed of the trees planted there by Dr. Hillebrand.

Dr. Hillebrand pointed out the necessity of protecting the native forests, and making the most of the native flora, but at the same time he realized the wisdom of strengthening the Hawaiian forests by introduced species. He favored the importation of seeds from abroad in quantities for distribution,—the appointment of wardens for the protection of the watersheds.

He felt that once our naked hills hills are properly reforested, "springs will soon bubble forth again from every nook and corner, between rocks and from under the fern-tree, to unite in streams which encased in a framework of bamboo canes and lianes will pour out of every valley and cover with fertility the now arid and sterile plains."

Many of these plains of Dr. Hillebrand's day have since been converted into sugar plantations by virtue of hydraulic engineering operations that have brought water from great distances, or from artesian sources. These enterprises have increased in a marked degree our dependence upon watershed forests. There is little in his exceedingly interesting paper that does not apply as vitally to the Hawaii of today as to the Hawaii of 1856.

Deterioration of Cuban Sugars.

In the report of the New York Sugar Trade Laboratory for 1919, by Dr. C. A. Browne, the following statement is made in regard to the loss of sugar in Cuba due to deterioration:

"A slight improvement was noted in the quality of the raw sugars tested during 1919, although the character of the product received in the latter part of the year was very inferior owing to its having undergone deterioration in storage. The losses from this cause in 1919 were probably the greatest in the history of the sugar industry. The loss during storage in Cuba alone, according to comparative analyses made at the Laboratory, is estimated at over $5,000,000, and when there is added to this sum the losses from deterioration in transit and in storage after delivery, the total losses from this cause in 1919 probably approximate one per cent of the total value of the Cuban crop."

We are luckily free from this kind of loss in Hawaii on account of the low moisture content and sanitary conditions of manufacture of our commercial sugar.

R. S. N.

Information for the Irrigator.*

By R. M. Allen.

Introduction.

Of all the factors influencing the productive capacity of the soil, there is none more important than soil moisture, which, in turn, in irrigated sections, is dependent on irrigation. We have more crop shortage from lack of moisture than from any other cause. The fertilizer which we apply in such large quantities is not available except when in solution, and without soil moisture it cannot pass into this state. Most plants contain from 70% to 90% water, and it has been found on the coast that it takes from 400 to 900 pounds of water to produce 1 pound of dry matter. We find that sugar cane contains from 60% to 70% moisture, and that it takes from 100 to 300 pounds of water to produce 1 pound of cane. For an ordinary crop this means from 10,000 to 20,000 tons, or a depth of from 7 to 14 feet of water per acre. Soil bacteria require moisture to make nitrogen and the mineral elements of plant food available. There is the closest relation existing between moisture in the soil and plant growth.

Expressing this in terms of dollars and cents, we see the relative importance of irrigation compared with other field operations.

In 1913-14, on wholly and partially irrigated plantations, $15,000,000 was spent in field operations. Out of this, $4,500,000, or 30 per cent, was for irrigating—including pumping, labor, and water costs. $2,700,000, or 18%, was for fertilizer, and $2,400,000, or 16%, was for harvesting. The balance was distributed in smaller amounts in planting, cultivating, etc. The point to bear in mind is that our irrigating cost is by far the largest single item in the field expense. Figures also show that 60% of the total irrigating cost is spent on labor, 30% on pumping, and the balance on the minor items.

Because of the large amounts of water used in the production of our crop, and because of the high cost of applying this, we are not wasting attention spent on the beneficial, economical use of water, which means the elimination of the losses, and the intelligent application of the water reaching the field.

Conveyance Losses from Pump to Field.

Probably the first loss occurs, assuming that the pumps are working properly, in seepage in the main ditches leading from the pump outlet to the reservoir. This has been found to run as high as 50% a mile, in exceptional cases, but frequently as high as 25% a mile. This, of course, will vary greatly, depending on the texture of the soil and subsoil, the position of the water table and natural drainage conditions, the age of the ditch, the depth of water, and its velocity. The remedy is lining the ditch, and where water is scarce, or where

* A lecture presented at the Short Course for Plantation Men, October, 1919.

it is pumped to high elevations, this is well worth while. The initial cost may seem high, but when the saving in water and the upkeep of the ditch are considered, it is realized that the expense is justified. A point to be impressed here is that the seepage in some ditches is greater than in others; in fact, many old ditches, in a compact soil, will be found in which no seepage occurs at all. Before any amount of money is spent on lining a ditch, measurements should be made to determine the extent of loss. Some ditches will require lining sooner than others.

Another loss occurs in the level ditches, but from the nature of their location they canont be lined. The remedy for this is to avoid running small heads of water in them. Frequently one or two men's water are used several days in succession when four or six men's water one day will do the same work at a lessened loss by evaporation and seepage. The percentage of loss is always smaller with large amounts of water than with small amounts of water. Hence the practical suggestion here is not to fill the level ditches any oftener than is necessary. This is well illustrated in the case of one manager on Kauai, who has a four-mile main ditch from which four or five gangs are supplied with water. Under his ordinary practice it would take thirty days to irrigate the area controlled by this ditch. Recently, however, being short of water, he has combined these small gangs into one big gang, and now not only covers the same area in twenty-two days, but has ten men's water more at the lower end of the ditch than he had before. With his one large gang closer supervision is also possible.

The losses occurring in the watercourse can only be lessened by carefully shutting the water in each line. This is not a serious loss, for it all reaches the cane at one place or another.

Disposal of Water that Reaches Field.

The water that finally reaches the field, probably only 40% to 60% of the water pumped—I speak of pumped water because it has a greater value, although mountain water may be equally valuable in time when water is scarce—is disposed of in four ways:

1. By surface run-off or waste.
2. By soil evaporation.
3. By plant transpiration.
4. By deep percolation.

The correct "economical use" of water is obtained when the above stated losses are reduced to the minimum.

Surface run-off is a loss due to leaky gates, and general careless, poor methods of irrigating. This is of minor importance, and on our large irrigated areas, closer supervision, particularly in big cane, is impractical.

Soil evaporation is automatically regulated by the cane closing in, and by the natural mulch that is formed by the self stripping of cane. In California, particularly in orchards, this loss is controlled by mulches of various sorts,

either soil mulches formed by cultivating to different depths, or by artificial mulches of straw. Our high humidity has an additional effect on checking this loss.

Transpiration is the natural process by which a circulation of plant foods in solution is maintained in the plant, or is the action through which the water serves a useful purpose. However, this action also takes place in weeds, and therefore the fewer the weeds, the cleaner the field, the more moisture that is available to the cane plant.

Thus it is that the loss with which we are most concerned is that occurring from deep percolation, by which I mean the passage of water, not retained by the soil, to depths below the zone of root growth. The useful water in the soil, known as the capillary water, is held by means of a thin film of water around each soil particle. Consequently, the soil having the greatest number of soil particles for a unit area is capable of holding the greatest amount of water. An acre foot of clay soil is composed of particles which have an estimated aggregate surface area of 16,000 acres, a loam soil 10,500 acres, and a sandy soil 3250. If a certain depth of irrigation water is applied to a loam soil and a sandy soil, any foot section of the former will retain more of the water than the same area of the latter, due to smaller, more numerous soil particles, and consequently greater area for the moisture films to form. As it is beyond our power to modify the size of the soil particles, it is up to us not to apply more water than our soils can hold.

Under our conditions, where the irrigating cost is so high, and our crop is so entirely dependent (in irrigated sections) on artificial irrigation, this is a point that cannot be emphasized too strongly. The object of an irrigation is to supply water to the plant roots. Now, the cane plant seldom sends roots more than four or five feet deep. Thus the water that we apply should all remain above that depth. At our Waipio Substation we have traced the movements of water to a depth of six feet under a 2″, a 6″, and a 9″ irrigation. We find—and the results are in accordance with data that have been secured elsewhere—that 3% of a 2″, 47% of a 6″, and 65% of a 9″ irrigation pass to depths below six feet. This was determined by sets of soil samples taken before and after the irrigation, and the increased percentage of moisture determined. The figures further show that, under Waipio conditions, it is impossible to store more than 4½ inches of water in the upper six feet of soil. This means that when more water than that is put on one of our fields, it passes below the reach of plant roots.

This point has several very practical connections. First, let me state that this figure, 4½ inches, or 122,000 gallons in six feet of soil, is for an ordinary loam soil. It would be much less for a sandy or gravelly soil, and greater for a finer-textured soil.

When fertilizer is put on with the irrigation water, and 40% or 50% of the latter passes below the root zone, it is easily seen that it carries with it some fertilizer, and the result is a triple loss—water, fertilizer, and the extra labor of putting the larger amount on.

Another application of this point is that it is impossible, above a certain point, to give a field a heavy irrigation and expect it to last longer than a lighter

irrigation, simply because a soil can only be made to hold a certain fixed amount of water.

A third and very important application is in connection with the first four or five waters on a plant field. It is generally true that small amounts of water will wet a soil to great depths, and that a large percentage of a heavy irrigation is wasted even on big cane with a fully developed root system four to five feet deep. A greater loss must therefore occur when a plant field, having a very shallow root system, is given anything but a very light irrigation. It has been noticed on most plantations that the irrigators fill the lines in a plant field just as full as possible. The larger the line, the more water that is put in. In an ordinary furrow this is enough water to wet the soil to a depth of at least eight feet, whereas it is only necessary to wet it to a depth of two feet at the most. If the hana-wai men can be trained to shut the water off before it reaches the end of the line instead of shutting it off after it has completely filled the lower end of the line, far better results will be obtained. This can be easily tried on any plant field by picking out two or three watercourses and instructing a man to run the water one minute in each line. You will find that the ordinary practice is to run it from two to four minutes. I believe that under any condition your watercourse that has had the smaller amount of water will come up just as rapidly, and germinate just as well as the balance of the field. This has an effect on the whole plantation, giving extra water and labor to the big cane, and allowing more frequent irrigation to the plant cane. Two small irrigations on plant cane, particularly H 109, are much more economical than one large irrigation.

A fourth point is that it is a bad practice to saturate a soil with water. Plants need air as well as water, and whenever water is put into the soil, an equal volume of air is displaced. To saturate a soil with water means to displace all the air, for when the spaces between the soil particles known as the "pore space" are not filled with water they are filled with air.

Water continually passing to lower depths will sooner or later raise the water table. This will vary greatly with conditions, but a rising and falling water table is always injurious to crops. A line must be drawn here between a water table that is always near the surface, and one that rises there only after an irrigation to recede slowly between irrigations. Alfalfa grows very well in California in some sections where free water is never less than three feet from the surface, while in other sections it is killed by free water that rises all of a sudden to five or six feet from the surface. Cane, as any other crop, will adjust itself to constant conditions, but it cannot vary its growth to meet sudden changes.

In this connection it should be noted that when irrigation water contains an appreciable amount of salt, it is essential that an excess of water be added to leach out the added salts. It is an open question whether this should be done through adding an excess amount of water at each irrigation, or by excessive irrigations periodically. Great care should be observed here, as heavy irrigations raise the water table and are liable to concentrate the salts near the surface, rather than leach them out.

California studies on the duty of water on alfalfa have brought to light some very interesting facts along this line.

(1) On five fields only one-third of the water applied to silt loam soils was retained in the upper six feet of soil where the principal root development of the alfalfa plant is located.

(2) The average quantity of water retained per acre foot of soil was 0.92 inch for silt loams, 0.71 inch for silts, 0.58 inch for clay loams, and 0.37 inch for clays.

(3) The general conclusion from all the California work is that without a doubt the prevailing practice was to apply far more water at a single application than the more porous soils can retain, and than the heavier soils can absorb.

A single comparison will show what is meant by this. On a certain clay loam field where 16 inches of water were applied, $4\frac{1}{2}$ inches were retained by the upper six feet of soil, while on an adjoining field of the same texture, $7\frac{1}{2}$ inches were applied, and 4 inches found in the upper six feet of soil. The smaller irrigation was thus doing the same work as the larger irrigation.

Meaning of Heavy and Light Irrigations.

The question very naturally comes up, "What is a heavy or light irrigation, and how do we know which we are doing?"

Before a discussion of this can be taken up, it is necessary to mention a few of the terms used in expressing amounts of water. Probably the most familiar expression is that 1,000,000 gallons will irrigate 100 acres. Now, there are two units of measurement:

(1) Those used to express the rate of flow or to express volume of water in motion. For example, we say that such and such a pump delivers 1,000,000 gallons per 24 hours.

(2) Those used to state a definite volume of water—at rest. For example, we say that 1,000,000 gallons per acre were used in such and such a field last year.

Now, although these are the units used by us to express water, they are clumsy and really convey no meaning. 1,000,000 gallons per acre means nothing to you or to me. It cannot be measured with a ruler, and it is hard to conceive what this would look like over an acre. If, however, you know that 1,000,000 gallons over an acre is equal to 3 feet of water over the same area, you have a definite idea as to how much water that is. This is a definite relation existing between 1,000,000 gallons and the unit known as an "acre foot," which is a depth of water of one foot over an acre. Two acre feet means a depth of two feet over one acre. The smaller unit generally used in expressing the amount of a single irrigation is the "acre inch." (As the name suggests, twelve acre inches are equal to one acre foot.) It means a depth of water of one inch over an acre. The only relation that is necessary to remember is that 1,000,000 gallons (I am speaking now of water not in motion) are equal to three acre feet. As a matter of fact, this is 3.07 acre feet, but it is sufficient to remember the even number. From this, of course, 2,000,000 gallons are equal to six (exactly 6.14) acre feet, or one acre foot is equal to 326,000 (exactly 325,850) gallons. On the

other hand, if you know that 1,000,000 gallons (three acre feet) were put on three acres, you also know that one acre foot went on each acre.

Now, when your pump engineer tells you that a pump is throwing 1,000,000 gallons, he means that you are getting 1.55 cubic feet every second. This is the unit known as the "second foot." One second foot, or one cubic foot per second, is equal to 450 (448.8) gallons per minute, or 650,000 (646,272) gallons per day. These figures may seem clumsy, but they are given because there is a definite, simple relation between water at rest and in motion where this system of expressing water is used, namely:

One second foot flowing for 24 hours will cover one acre to a depth of two feet (1.98), or it will deliver two acre feet.

Remembering this, it is easy to calculate what happens when ten second feet flowing for 12 hours covers 40 acres. Ten second feet for 24 hours equals 20 acre feet. Ten second feet for 12 hours equals 10 acre feet. Ten acre feet over 40 acres equals 0.25 acre feet or 3.00 acre inches on each acre.

Now, to come back to our familiar expression, 1,000,000 gallons per 100 acres. This does not convey any very great impression to us. However, 1,000,000 gallons equals 1.55 second feet, which in 24 hours, or one day, gives 3.10 acre feet. In 365 days we have 1132 acre feet over 100 acres, or 11.32 feet over 1 acre. Thus, 1,000,000 gallons per 100 acres means approximately 11 feet of water over each acre. This illustrates very clearly why the second foot-acre foot units are easier to handle. We can conceive of 11 feet of water on each acre. Assuming that we irrigate twice a month, this is 24 5½-inch irrigations, or 149,000 gallons.

From our experience so far in irrigation we speak of anything over a five-inch irrigation as heavy, and anything under as a light irrigation.

This also illustrates the two methods of expressing what is known as the "duty of water," which is the acreage served by a quantity of water, namely:

(1) In acres served by a given unit of flow.
(2) In acre-feet per acre.

In irrigation, the duty of water means the amount of water applied per acre in the production of a crop. When the amount of water per acre used is small, the duty is high, and when a large amount is used per acre, the duty is low. In the States the duty varies greatly. In California the duty ranges from 1 second foot to 200 acres to 1 second foot to 120 acres, a high duty compared with Utah, where a duty of 1 second foot to 20 to 70 acres is prevalent. A duty of 1 second foot to 20 acres means 36 feet per acre per year, or 12 acre feet in four months, which is the average irrigating period on the Coast. Only 2½ feet are needed to produce a crop in the locality, hence the extravagant waste of water is seen.

As has been stated, our duty of "1,000,000 gallons per day per 100 acres," or 1.55 second feet per 100 acres, which is 1 second foot to 64 acres, means a depth of 11.3 feet of water on each acre per year. Whether this is a high or low duty we are at present unable to say.

This brings us to a few calculations that should be made to check up our irrigation practice.

(1) I have a flow of 10,000,000 gallons (15.50 second feet). How many acres will that handle, giving a 4-inch irrigation (108,000 gallons) every 20 days?

1 second foot = 2.0 acre feet per day.
15.50 " " = 31.0 " " " "
15.50 " " = 31 x 20 = 620 acre feet in 20 days.
4 acre inches = 0.333 acre feet per acre.

$$\frac{620}{.333} = 1860$$ acres which can be given a 4-inch irrigation every 20 days with the above flow. The duty in this case is:

15.50 second feet to 1860 acres.
1 " foot to 120 acres, or
1,000,000 gallons to 186 acres.

(2) Take a reverse proposition. A plantation has 4000 acres which should be given a 4-inch irrigation every 20 days. How much water is needed?

4 acre inches = 0.333 acre feet on each acre.
$4000 \times 0.333 = 1332$ acre feet needed.

Now, how great a flow will in 20 days give 1332 acre feet?

1 second foot in 1 day gives 2 acre feet.
1 second foot in 20 days gives 40 acre feet.

How many second feet will in 20 days give 1332 acre feet?

$$\frac{1332}{40} = 33.3 \text{ second feet or } 650{,}000 \times 33.3 = 21{,}600{,}000 \text{ gallons.}$$

(3) A third, and probably the most practical question, is: If I am being given a flow of 20,000,000 gallons per day, and I am irrigating 2000 acres every 20 days, how much water am I giving per irrigation?

20,000,000 gallons = 31.0 second feet.
1 second foot in 1 day = 2 acre feet.
31 " feet " 1 " = 62 " "
31 " " " 20 days = 1240 " "

This 1240 acre feet is distributed over 2000 acres. Therefore each acre is getting

$$\frac{1240}{2000} = 0.62$$ acre feet, or 7.4 acre inches (201,000 gallons).

The main value of these calculations is that it will enable you to get an idea as to how you are using your water. It is safe to say that the maximum amount of water that the cane can use is five or six inches every two weeks, and in some cases I think it will be found that much more is being used.

Three factors must be known before the amount or depth, as we more properly call it, of an irrigation is known: Amount of flow or discharge; time of flow, and the acreage. The last two are simple. Generally we know that it takes one man one hour or two hours to irrigate one watercourse which is 0.25 of an acre. (This varies, of course, but it is easily determined.) It remains, therefore, only to determine the flow, or what a "man's water" in Hawaii, or "head" in California, really is. There are many ways of measuring water, but for our purposes we need only consider four:

1. Weirs.
2. Current meters.

3. Surface flow method.
4. Rating flumes.

This is a very large subject. Many volumes have been written on it, so only the basic facts will be mentioned. I have already discussed the units of measurement. The second foot-acre foot unit is the one universally used, and all tables for weirs and current meters are based on this.

The weir is the most common device for measuring water, because it is cheap, simple to construct, and, when properly installed, is accurate. Three types are most common—the trapezoidal or Cipolletti weir, the rectangular weir with end contractions, and the triangular weir. The Cipolletti weir has been very popular because of the fact that with a given head the discharge was proportional to the length of the crest; that is, six inches on a two-foot weir would give twice the discharge of six inches over a one-foot weir. However, accurate tables are available for rectangular weirs, and as this type is easier to construct, they are to be preferred for our purposes. Triangular weirs are used for measuring small heads of water, which they do more accurately than the other types. They are simple to construct, and can be used in watercourses to measure one man's water. The conditions required for accuracy in the above-mentioned weirs are about the same, and are as follows:

1. The upstream crest should be sharp and smooth.

2. The distances of its crest and sides from the bottom and sides of the ditch should be not less than twice the depth of water over the weir, and never less than one foot.

3. The overflow sheet should only touch the upstream edge of the notch. If made of wood it should be beveled.

4. Air should circulate freely on all sides of the sheet.

5. It should be level and vertical.

6. The measurements should be taken from 4 to 10 feet upstream. Generally a post is put in, and a nail driven at exactly the same elevation as the crest of the weir. This nail can be approximately set by means of an ordinary carpenter's level and a piece of board. Then, when the water is turned in, it can be accurately set, using the water as a level. The measurement is then made by means of a ruler, placing zero on the nail thus set. This may be either in inches or in tenths of feet. Formulae are given for the discharge over weirs of various types, but it is unnecessary to know these, for tables are readily available which give the discharge over weirs of different crest lengths. For convenience in using these it is best to make weirs with a crest of even-foot and half-foot lengths.

There has recently come to our attention a device known as the "Lyman Irrigation Meter," which, if it proves successful, will increase the efficiency of weirs many times. This device measures and records all the water passing over the weir, regardless of the changing level in the ditch. One of these has been ordered, and as soon as tests have been conducted, a report will be made on it.

Where the fall in the ditch is great, it is best to have a short crest, and consequently a greater depth, while with a medium grade a longer crest, and consequent shorter depth, is desirable. Generally speaking, the depth of water flowing over the crest should not be greater than one-third of the length of the crest.

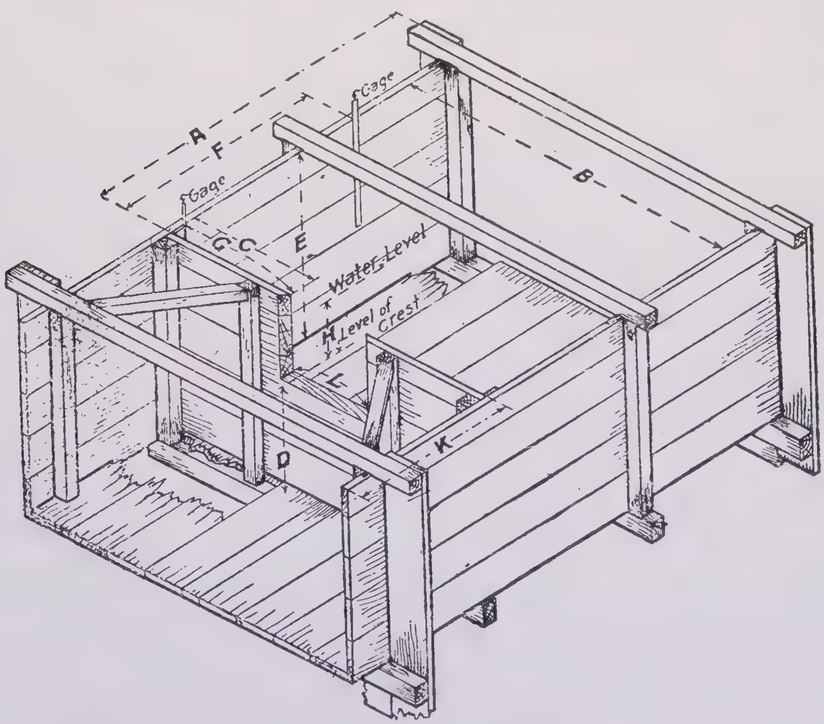
Table 1, taken from Farmers' Bulletin 813, by V. M. Cone, Irrigation Engineer, gives the sizes of weirs best adapted to measuring streams of water varying from one-half to twenty-two cubic feet per second (323,000 to 14,000,000 gallons per day).

TABLE 1.—WEIR BOX DIMENSIONS FOR RECTANGULAR AND CIPOLLETTI WEIRS.

(All dimensions are in feet. The letters at the head of the column refer to Fig. 1.)

RECTANGULAR AND TRAPEZOIDAL WEIRS WITH END CONTRACTIONS.

Flow		H	L	A	K	B	E	C	D	F
Sec. Feet	Million Gallons per 24 Hours	Maximum head.	Length of weir crest.	Length of box above weir notch.	Length of box below weir notch.	Total width of box.	Total depth of box.	End of crest to side.	Crest to bottom.	Point of measurement upstream from crest.
½- 3	323,000- 1,900,000	1.0	1	6	2	5½	3½	2¼	2	4
2- 5	1,300,000- 3,230,000	1.1	1½	7	3	7	4	2¾	2½	4½
4- 8	2,600,000- 5,170,000	1.2	2	8	4	8½	4½	3¼	2¾	5
6-14	3,900,000- 9,000,000	1.3	3	9	5	12	5	4½	3¼	5½
10-22	6,500,000-14,200,000	1.5	4	10	6	14	5½	5	3½	6



Plan of weir box. Weir may be placed in box built of lumber or cement, or in enlarged section of ditch.

It is stated that weir boxes of these sizes will give results within one per cent of the correct values, providing the above-mentioned conditions necessary for weir crests and sides are followed.

TABLE 2.—DISCHARGE TABLES FOR RECTANGULAR WEIRS.*

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
0.20	2⅜	0.291	0.439	0.588	0.887	1.19
.21	2½	.312	.472	.632	.954	1.28
.22	2⅝	.335	.505	.677	1.02	1.37
.23	2¾	.358	.539	.723	1.09	1.46
.24	2⅞	.380	.574	.769	1.16	1.55
.25	3	.404	.609	.817	1.23	1.65
.26	3⅛	.428	.646	.865	1.31	1.75
.27	3¼	.452	.682	.914	1.38	1.85
.28	3⅜	.477	.720	.965	1.46	1.95
.29	3½	.502	.758	1.02	1.53	2.05
.30	3⅝	.527	.796	1.07	1.61	2.16
.31	3¾	.553	.836	1.12	1.69	2.26
.32	3 13/16	.580	.876	1.18	1.77	2.37
.33	3 15/16	.606	.916	1.23	1.86	2.48
.34	4 1/16	.634	.957	1.28	1.94	2.60
.35	4 3/16	.661	.999	1.34	2.02	2.71
.36	4 5/16	.688	1.04	1.40	2.11	2.82
.37	4 7/16	.717	1.08	1.45	2.20	2.94
.38	4 9/16	.745	1.13	1.51	2.28	3.06
.39	4 11/16	.774	1.17	1.57	2.37	3.18
.40	4 13/16	.804	1.21	1.63	2.46	3.30
.41	4 15/16	.833	1.26	1.69	2.55	3.42
.42	5 1/16	.863	1.30	1.75	2.65	3.54
.43	5 3/16	.893	1.35	1.81	2.74	3.67
.44	5¼	.924	1.40	1.88	2.83	3.80
.45	5⅜	.955	1.44	1.94	2.93	3.93
.46	5½	.986	1.49	2.00	3.03	4.05
.47	5⅝	1.02	1.54	2.07	3.12	4.18
.48	5¾	1.05	1.59	2.13	3.22	4.32
.49	5⅞	1.08	1.64	2.20	3.32	4.45
.50	6	1.11	1.68	2.26	3.42	4.58
.51	6⅛	1.15	1.73	2.33	3.52	4.72
.52	6¼	1.18	1.78	2.40	3.62	4.86
.53	6⅜	1.21	1.84	2.46	3.73	4.99
.54	6½	1.25	1.89	2.53	3.83	5.13
.55	6⅝	1.28	1.94	2.60	3.94	5.27
.56	6¾	1.31	1.99	2.67	4.04	5.42
.57	6 13/16	1.35	2.04	2.74	4.15	5.56
.58	6 15/16	1.38	2.09	2.81	4.26	5.70
.59	7 1/16	1.42	2.15	2.88	4.36	5.85
.60	7 3/16	1.45	2.20	2.96	4.47	6.00
.61	7 5/16	1.49	2.25	3.03	4.59	6.14
.62	7 7/16	1.52	2.31	3.10	4.69	6.29

* From Circular No. 36, Utah Agricultural College Experiment Station, by O. W. Israelsen.

TABLE 2 (CONTINUED).—DISCHARGE TABLES FOR RECTANGULAR WEIRS.

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
.63	7 9/16	1.56	2.36	3.17	4.81	6.44
.64	7 11/16	1.60	2.42	3.25	4.92	6.59
.65	7 13/16	1.63	2.47	3.32	5.03	6.75
.66	7 15/16	1.67	2.53	3.40	5.15	6.90
.67	8 1/16	1.71	2.59	3.47	5.26	7.05
.68	8 3/16	1.74	2.64	3.56	5.38	7.21
.69	8¼	1.78	2.70	3.63	5.49	7.36
.70	8⅜	1.82	2.76	3.71	5.61	7.52
.71	8½	1.86	2.81	3.78	5.73	7.68
.72	8⅝	1.90	2.87	3.86	5.85	7.84
.73	8¾	1.93	2.93	3.94	5.97	8.00
.74	8⅞	1.97	2.99	4.02	6.09	8.17
.75	9	2.01	3.05	4.10	6.21	8.33
.76	9⅛	2.05	3.11	4.18	6.33	8.49
.77	9¼	2.09	3.17	4.26	6.45	8.66
.78	9⅜	2.13	3.23	4.34	6.58	8.82
.79	9½	2.17	3.29	4.42	6.70	8.99
.80	9⅝	2.21	3.35	4.51	6.83	9.16
.81	9¾	2.25	3.41	4.59	6.95	9.33
.82	9 13/16	2.29	3.47	4.67	7.08	9.50
.83	9 15/16	2.33	3.54	4.75	7.21	9.67
.84	10 1/16	2.37	3.60	4.84	7.33	9.84
.85	10 3/16	2.41	3.66	4.92	7.46	10.01
.86	10 5/16	2.46	3.72	5.01	7.59	10.19
.87	10 7/16	2.50	3.79	5.10	7.72	10.36
.88	10 9/16	2.54	3.85	5.18	7.85	10.54
.89	10 11/16	2.58	3.92	5.27	7.99	10.71
.90	10 13/16	2.62	3.98	5.35	8.12	10.89
.91	10 15/16	2.67	4.05	5.44	8.25	11.07
.92	11 1/16	2.71	4.11	5.53	8.38	11.25
.93	11 3/16	2.75	4.18	5.62	8.52	11.43
.94	11¼	2.79	4.24	5.71	8.65	11.61
.95	11⅜	2.84	4.31	5.80	8.79	11.79
.96	11½	2.88	4.37	5.89	8.93	11.98
.97	11⅝	2.93	4.44	5.98	9.06	12.16
.98	11¾	2.97	4.51	6.07	9.20	12.34
.99	11⅞	3.01	4.57	6.15	9.34	12.53
1.00	12	3.06	4.64	6.25	9.48	12.72
1.01	12⅛	....	4.71	6.34	9.62	12.91
1.02	12¼	....	4.78	6.43	9.76	13.10
1.03	12⅜	....	4.85	6.52	9.90	13.28
1.04	12½	....	4.92	6.62	10.04	13.47
1.05	12⅝	....	4.98	6.71	10.18	13.66
1.06	12¾	....	5.05	6.80	10.32	13.85
1.07	12 13/16	....	5.12	6.90	10.46	14.04
1.08	12 15/16	....	5.20	6.99	10.61	14.24
1.09	13 1/16	....	5.26	7.09	10.75	14.43
1.10	13 3/16	....	5.34	7.19	10.90	14.64
1.11	13 5/16	....	5.41	7.28	11.04	14.83

TABLE 2 (CONCLUDED).—DISCHARGE TABLES FOR RECTANGULAR WEIRS.

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
1.12	13 7/16	....	5.48	7.38	11.19	15.03
1.13	13 9/16	....	5.55	7.47	11.34	15.22
1.14	13 11/16	....	5.62	7.57	11.48	15.42
1.15	13 13/16	....	5.69	7.66	11.64	15.62
1.16	13 15/16	....	5.77	7.76	11.79	15.82
1.17	14 1/16	....	5.84	7.86	11.94	16.02
1.18	14 3/16	....	5.91	7.96	12.09	16.23
1.19	14¼	....	5.98	8.06	12.24	16.43
1.20	14⅜	....	6.06	8.16	12.39	16.63
1.21	14½	....	6.13	8.26	12.54	16.83
1.22	14⅝	....	6.20	8.35	12.69	17.03
1.23	14¾	....	6.28	8.46	12.85	17.25
1.24	14⅞	....	6.35	8.56	12.99	17.45
1.25	15	....	6.43	8.66	13.14	17.65
1.26	15⅛	....	....	....	13.30	17.87
1.27	15¼	....	....	....	13.45	18.07
1.28	15⅜	....	....	....	13.61	18.28
1.29	15½	....	....	....	13.77	18.50
1.30	15⅝	....	....	....	13.93	18.71
1.31	15¾	....	....	....	14.09	18.92
1.32	15 13/16	....	....	....	14.24	19.12
1.33	15 15/16	....	....	....	14.40	19.34
1.34	16 1/16	....	....	....	14.56	19.55
1.35	16 3/16	....	....	....	14.72	19.77
1.36	16 5/16	....	....	....	14.88	19.98
1.37	16 7/16	....	....	....	15.04	20.20
1.38	16 9/16	....	....	....	15.20	20.42
1.39	16 11/16	....	....	....	15.36	20.64
1.40	16 13/16	....	....	....	15.53	20.86
1.41	16 15/16	....	....	....	15.69	21.08
1.42	17 1/16	....	....	....	15.85	21.29
1.43	17 3/16	....	....	....	16.02	21.52
1.44	17¼	....	....	....	16.19	21.74
1.45	17⅜	....	....	....	16.34	21.96
1.46	17½	....	....	....	16.51	22.18
1.47	17⅝	....	....	....	16.68	22.41
1.48	17¾	....	....	....	16.85	22.64
1.49	17⅞	....	....	....	17.01	22.85
1.50	18	....	....	....	17.17	23.08

TABLE 3.—DISCHARGE TABLES FOR CIPOLLETTI WEIRS.*

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
0.20	2⅜	0.30	0.45	0.60	0.90	1.20
.21	2½	.32	.48	.64	.97	1.29
.22	2⅝	.35	.52	.69	1.04	1.38
.23	2¾	.37	.55	.74	1.11	1.47
.24	2⅞	.39	.59	.79	1.18	1.57
.25	3	.42	.63	.84	1.25	1.67
.26	3⅛	.45	.67	.89	1.33	1.77
.27	3¼	.47	.70	.94	1.40	1.87
.28	3⅜	.50	.74	.99	1.48	1.97
.29	3½	.53	.79	1.04	1.56	2.08
.30	3⅝	.56	.83	1.10	1.64	2.19
.31	3¾	.59	.87	1.15	1.73	2.30
.32	3 13/16	.61	.91	1.21	1.80	2.41
.33	3 15/16	.64	.95	1.27	1.89	2.52
.34	4 1/16	.67	1.00	1.32	1.98	2.64
.35	4 3/16	.70	1.04	1.38	2.07	2.75
.36	4 5/16	.73	1.09	1.44	2.16	2.87
.37	4 7/16	.77	1.13	1.50	2.25	2.99
.38	4 9/16	.80	1.18	1.57	2.34	3.11
.39	4 11/16	.83	1.23	1.63	2.43	3.24
.40	4 13/16	.87	1.28	1.69	2.53	3.36
.41	4 15/16	.90	1.32	1.76	2.62	3.49
.42	5 1/16	.93	1.37	1.82	2.72	3.61
.43	5 3/16	.97	1.42	1.89	2.81	3.74
.44	5¼	1.00	1.47	1.95	2.91	3.87
.45	5⅜	1.04	1.53	2.02	3.01	4.01
.46	5½	1.07	1.58	2.09	3.11	4.14
.47	5⅝	1.11	1.63	2.16	3.21	4.28
.48	5¾	1.15	1.68	2.23	3.32	4.41
.49	5⅞	1.18	1.74	2.30	3.42	4.55
.50	6	1.22	1.79	2.37	3.53	4.69
.51	6⅛	1.26	1.85	2.44	3.64	4.83
.52	6¼	1.30	1.90	2.51	3.74	4.97
.53	6⅜	1.34	1.96	2.59	3.85	5.12
.54	6½	1.38	2.02	2.66	3.96	5.26
.55	6⅝	1.42	2.07	2.74	4.07	5.41
.56	6¾	1.46	2.13	2.81	4.18	5.56
.57	6 13/16	1.50	2.19	2.89	4.30	5.71
.58	6 15/16	1.54	2.25	2.97	4.41	5.86
.59	7 1/16	1.58	2.31	3.05	4.53	6.01
.60	7 3/16	1.62	2.37	3.13	4.64	6.17
.61	7 5/16	1.67	2.43	3.20	4.76	6.32
.62	7 7/16	1.71	2.49	3.28	4.88	6.47
.63	7 9/16	1.75	2.55	3.37	5.00	6.63
.64	7 11/16	1.80	2.62	3.45	5.12	6.79
.65	7 13/16	1.84	2.68	3.53	5.24	6.95
.66	7 15/16	1.89	2.75	3.61	5.36	7.11
.67	8 1/16	1.93	2.81	3.70	5.48	7.28

* From Circular No. 36, Utah Agricultural College Experiment Station, by O. W. Israelsen.

TABLE 3 (CONTINUED).—DISCHARGE TABLES FOR CIPOLLETTI WEIRS.

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
.68	8 3/16	1.98	2.87	3.79	5.61	7.44
.69	8¼	2.02	2.94	3.87	5.73	7.61
.70	8⅜	2.07	3.01	3.95	5.86	7.77
.71	8½	2.12	3.07	4.04	5.99	7.94
.72	8⅝	2.16	3.14	4.13	6.12	8.11
.73	8¾	2.21	3.21	4.22	6.24	8.28
.74	8⅞	2.26	3.28	4.31	6.38	8.45
.75	9	2.31	3.35	4.40	6.51	8.62
.76	9⅛	2.36	3.42	4.49	6.64	8.80
.77	9¼	2.41	3.49	4.58	6.77	8.97
.78	9⅜	2.46	3.56	4.67	6.90	9.15
.79	9½	2.51	3.63	4.76	7.04	9.33
.80	9⅝	2.56	3.70	4.85	7.18	9.51
.81	9¾	2.61	3.77	4.95	7.31	9.69
.82	9 13/16	2.66	3.84	5.04	7.45	9.87
.83	9 15/16	2.71	3.92	5.14	7.59	10.05
.84	10 1/16	2.77	3.99	5.23	7.73	10.23
.85	10 3/16	2.82	4.07	5.33	7.87	10.42
.86	10 5/16	2.87	4.14	5.43	8.01	10.60
.87	10 7/16	2.93	4.22	5.52	8.15	10.79
.88	10 9/16	2.98	4.29	5.62	8.30	10.98
.89	10 11/16	3.04	4.37	5.72	8.44	11.17
.90	10 13/16	3.09	4.45	5.82	8.59	11.36
.91	10 15/16	3.15	4.53	5.92	8.73	11.55
.92	11 1/16	3.20	4.60	6.02	8.88	11.74
.93	11 3/16	3.26	4.68	6.13	9.03	11.94
.94	11¼	3.32	4.76	6.23	9.17	12.13
.95	11⅜	3.37	4.84	6.33	9.32	12.33
.96	11½	3.43	4.92	6.44	9.48	12.53
.97	11⅝	3.49	5.00	6.55	9.62	12.72
.98	11¾	3.55	5.09	6.64	9.78	12.92
.99	11⅞	3.61	5.17	6.75	9.93	13.12
1.00	12	3.67	5.25	6.86	10.08	13.32
1.01	12⅛	....	5.33	6.96	10.24	13.53
1.02	12¼	....	5.42	7.07	10.40	13.73
1.03	12⅜	....	5.50	7.18	10.55	13.94
1.04	12½	....	5.59	7.29	10.71	14.15
1.05	12⅝	....	5.67	7.40	10.87	14.35
1.06	12¾	....	5.76	7.51	11.03	14.56
1.07	12 13/16	....	5.84	7.62	11.18	14.76
1.08	12 15/16	....	5.93	7.73	11.35	14.98
1.09	13 1/16	....	6.02	7.84	11.51	15.19
1.10	13 3/16	....	6.11	7.96	11.68	15.41
1.11	13 5/16	....	6.20	8.07	11.84	15.62
1.12	13 7/16	....	6.29	8.18	12.00	15.84
1.13	13 9/16	....	6.37	8.29	12.16	16.04
1.14	13 11/16	....	6.46	8.41	12.33	16.26
1.15	13 13/16	....	6.56	8.53	12.50	16.48
1.16	13 15/16	....	6.65	8.65	12.67	16.70

TABLE 3 (CONCLUDED).—DISCHARGE TABLES FOR CIPOLLETTI WEIRS.

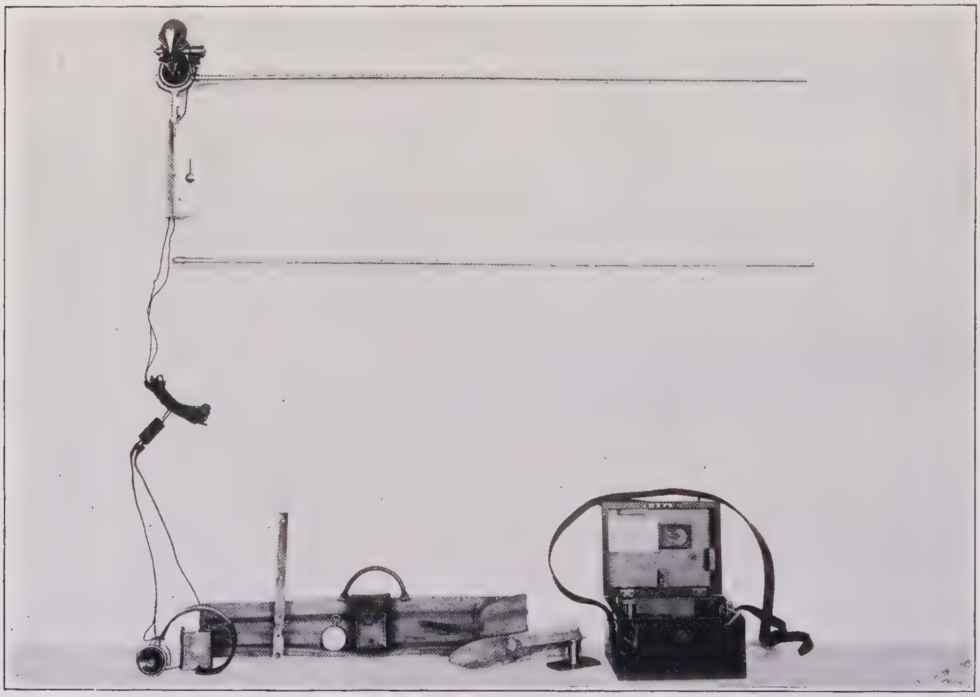
Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
1.17	14 1/16	....	6.74	8.76	12.84	16.93
1.18	14 3/16	....	6.83	8.88	13.01	17.15
1.19	14¼	....	6.93	9.10	13.18	17.37
1.20	14⅜	....	7.02	9.12	13.35	17.59
1.21	14½	....	7.11	9.24	13.52	17.81
1.22	14⅝	....	7.20	9.36	13.69	18.03
1.23	14¾	....	7.30	9.48	13.87	18.27
1.24	14⅞	....	7.40	9.60	14.04	18.49
1.25	15	....	7.49	9.72	14.21	18.71
1.26	15⅛	....	....	....	14.39	18.95
1.27	15¼	....	....	....	14.56	19.17
1.28	15⅜	....	....	....	14.74	19.41
1.29	15½	....	....	....	14.92	19.65
1.30	15⅝	....	....	....	15.11	19.88
1.31	15¾	....	....	....	15.29	20.12
1.32	15 13/16	....	....	....	15.46	20.34
1.33	15 15/16	....	....	....	15.64	20.58
1.34	16 1/16	....	....	....	15.82	20.82
1.35	16 3/16	....	....	....	16.01	21.06
1.36	16 5/16	....	....	....	16.19	21.29
1.37	16 7/16	....	....	....	16.37	21.53
1.38	16 9/16	....	....	....	16.57	21.78
1.39	16 11/16	....	....	....	16.75	22.02
1.40	16 13/16	....	....	....	16.94	22.27
1.41	16 15/16	....	....	....	17.13	22.51
1.42	17 1/16	....	....	....	17.31	22.75
1.43	17 3/16	....	....	....	17.51	23.01
1.44	17¼	....	....	....	17.70	23.26
1.45	17⅜	....	....	....	17.89	23.50
1.46	17½	....	....	....	18.08	23.75
1.47	17⅝	....	....	....	18.28	24.01
1.48	17¾	....	....	....	18.47	24.26
1.49	17⅞	....	....	....	18.66	24.50
1.50	18	....	....	....	18.85	24.75

Current meters are restricted in their use, being expensive, and requiring a more or less skilled operator. They are used in making seepage measurements, and generally where the installation of a weir is not warranted.

A very simple means of measuring the quantity of water flowing in a ditch is by what is known as the "surface float" method. In accuracy this is not to be compared with either the weir or current meter, and I speak of it only as a way out when neither of the others is available.

The principle of the method lies in the fact that area in square feet, times velocity in feet per second, is equal to discharge in cubic feet per second. The method is as follows: Select a uniform section of ditch from 50 to 100 feet long. At two or three points obtain the area, by measuring the depth and the width in several points, and averaging these figures. The width times the average depth

gives the area. Get this area at several points and average them. Say, for example, this is two square feet. The velocity is then obtained by timeing a piece of wood or cane stump over this 50 or 100-foot section. Assume that your watch shows that it took 25 seconds for the chip to travel 100 feet. This shows that the surface velocity is four feet per second. But we have the average area. So we must have the average velocity. Water is always flowing faster on the surface than at lower depths. To obtain the mean velocity it is necessary to apply a certain coefficient. The selection of the constant depends on the area and type of ditch, but for our purpose it is safe to give it a value of 0.65 if it is an earthen ditch and fairly clean, and 0.60 if it is a very weedy earthen ditch, having an area anywhere from 2 to 10 square feet. Thus, if our ditch is clean our velocity becomes $4.0 \times 0.65 = 2.60$ feet per second. The discharge is then $2.6 \times 2 = 5.2$



Small Price rod, current meter, and equipment used in measurement of water.

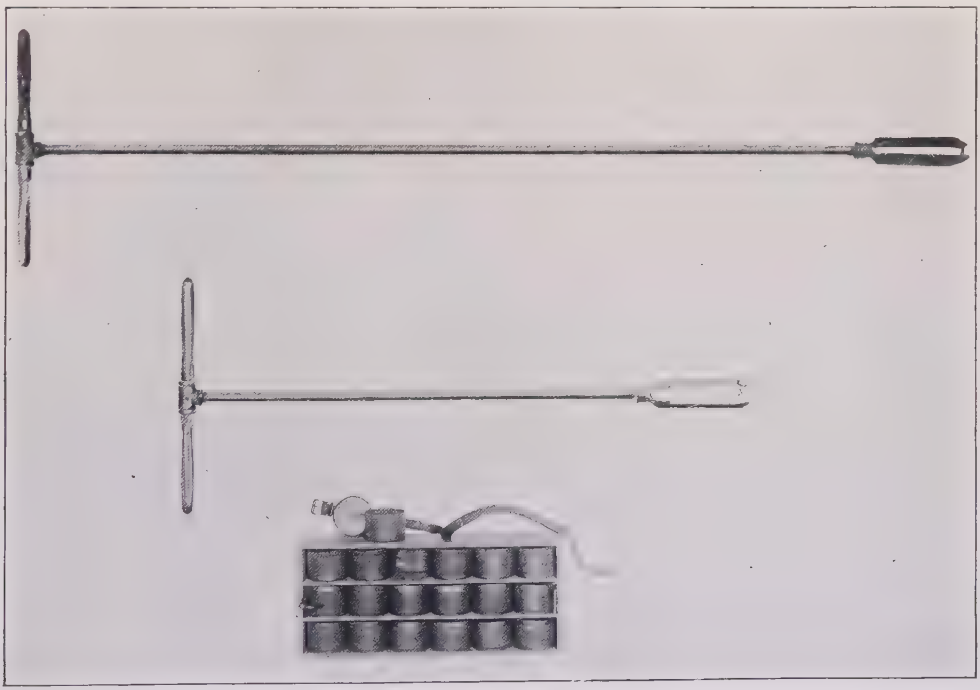
cubic feet per second. Now, remembering that 1 second foot in 24 hours delivers 2 acre feet, we see that our present flow will cover 1 acre 10½ feet deep in 24 hours.

Rating stations consist of a selected section of ditch, whose discharge is known for any depth, generally indicated by a permanent gauge rod. The largest source of error is the changing of the cross-section of the ditch, due to erosion or silt deposits. So in earth ditches it is advisable either to line a section, or to construct a rating flume. This flume should be 12 to 20 feet long (not less than twice the width of the ditch), and about the same width and depth as the ditch itself. The floor should be level (transversally) and should be set to the grade of the ditch; it should be set about 1 to 1½ inches above

the bed of the ditch so that all the silt will be carried through. The flume should be located far enough away from level gates so as to be away from the back-water when the gate is closed. The relation between the depth of water and the corresponding discharge is obtained by actually measuring the flow for different depths in the flume. This is known as rating the flume, and the results are plotted to give the rating curve from which the discharge can be found for any depth.

Once such a flume is rated, which requires more or less experience, the device makes a very simple, efficient means of measuring water.

I hope that this information on measuring devices will be of some value to you. Without a doubt it is a valuable phase of the subject, and I am sure will show you startling results. It is the means of checking up the pumps, locating



Soil-sampling outfit for moisture determination, showing three and six-foot auger, together with air-tight cans for transporting samples from field to laboratory.

serious seepage losses, and of showing you how evenly your water supply is distributed over your plantation. Sandy soils retain less water than loam soils. Are they getting less water or are they getting more where *you* are responsible for the irrigation? Fields when first planted do not require as heavy irrigations as do ratoon fields just starting. How are *you* irrigating your newly-planted fields? A few weirs, rating stations, or even a few casual float measurements will show many things. "The key to the economical use of water," a term much used in California, is measurement.

Soil Moisture and Irrigation.

Mention has been made of the value of soil moisture in tracing losses by

deep percolation. This phase of irrigation studies leads to many other points. For instance, what is the value of a 1-inch rain? If we find from our soil moisture studies, as we have found at Waipio, that it is possible under irrigation to store 1 inch in the upper foot, we see that this rain does no more than wet the surface 10 or 12 inches. This is fine for plant cane, but of little value to ratoon cane, whose roots are farther from the surface. In California they have found that an inch of rain falling on a very dry surface will seldom wet more than 6 inches of soil. A half-inch rain is of no value unless the surface is fairly moist from a preceding rain. This brings out the fact that moisture is carried faster into a moist soil than into a dry soil.

That the soil moisture content can be used as an indication of the time to irrigate has been fairly well proven in California and other western states. The following results have been obtained:

	Minimum Moisture %	Yield
Potatoes	23	292 bu.
	20	308 bu.
	17	176 bu.
Clover	20	17 tons
	17	19.3 tons
	14	19.6 tons

Generally they find that a decreased yield results from keeping a field too wet, or too dry. This, of course, depends to a large extent on the type of soil, age of crop, and other factors. We have found that on our medium soil at Waipio whenever cane looks as if it needed water, the moisture percentage is below 23%. This means that when our moisture percentage gets as low as 25% it is time to irrigate, for we should not wait until the cane is suffering before we apply water, for at such time its growth is checked.

The time to shut off irrigation water before harvesting is a factor that cannot be overlooked. We have recently harvested an experiment at Waipio where irrigation water was withheld 40, 60 and 80 days before harvesting. Juice samples showed that the best juices were obtained where the cane had not been irrigated for 60 days. Where the water had been shut off for 80 days the cane had started to go back, and the juices, though better than where the water had been removed only 40 days, were poorer than the 60-day juices. This is a factor that will, of course, vary with the location, soil type, etc., so we can only say now that this is a point worthy of attention.

An interesting observation was also made this year on the advisability of irrigating as soon as possible after harvesting. One of our fields was irrigated immediately after harvesting with the exception of four or five watercourses. At the end of ten days there was such a marked difference in germination in favor of that which had been irrigated that we were forced to irrigate the remaining portion in order to get the uniform stand necessary for the experiment that had been planned for this field. The observation indicates that a better stand will be obtained by following this practice wherever possible. This

is, of course, subject to conditions. Heavy rains just prior to harvesting may lessen this need.

Does more water produce more cane? This is a question which can only be answered by experiments. We have done some work along this line, but hardly enough to draw any definite conclusions. The opinion based on our data to date, and on the California work that has been done on other crops, is that the yield of cane varies with the water applied to a certain point. Between this point and another point there is a slight increase in yield not sufficient to pay for the excess water, and above this second point there is an actual decrease in the yield due to the excess water.

A great deal of data along this line is available from work done in California on various crops. As a result of five years' experimenting with alfalfa it has been found that the maximum results were obtained with 36 inches of irrigation water. The results are as follows:

Depth of Irrigation.	Yield.
0 irrigation	3.80 tons alfalfa
12″ "	5.60 " "
18″ "	6.80 " "
24″ "	7.90 " "
30″ "	9.00 " "
36″ "	9.30 " "
48″ "	9.00 " "
60″ "	8.40 " "

The greatest yield with potatoes was obtained with 60 inches of water, but only 10% greater than the next largest yield obtained with 20 inches of water. The results of this work show that from 18 inches to 20 inches are the water requirement for the maximum yield of potatoes.

Work on sugar beets shows that above 20 inches of water there is only a very slight increase in yield. Duty of water data on barley shows that the greatest yield was obtained with 7.50 inches, and the smallest with 40 inches of water. Oats gave a maximum yield with 20 inches, and with wheat the yield with 15 and 50 inches was practically the same. The sugar beet work also shows that the greatest purity was obtained with the smaller application of water.

Of course, these data all pertain to crops of a different nature than sugar cane, but because the tendencies are so general for all other crops, we are led to suppose that possibly it is true for our crop. The only experiment which we have harvested gave practically identical yields for applications of 2 inches, 6 inches and 9 inches per irrigation. However, the experiment was only preliminary, and not accurate enough to draw conclusions. We can conclude, however, that the subject is of enough interest to look into. If we can produce the same yields of cane with smaller amounts of water we are opening the road for great savings. If we can reduce the time of irrigating 1 minute per line, we would save $12 per acre from the labor end of irrigating alone, to say nothing of the saving in water and pump expense.

Whether or not every other row irrigation is practical is dependent on whether the lateral percolation is sufficient to wet the area where water has not been applied directly. With hilled cane a very practical method of handling trash, and a method possibly to be recommended for this form of irrigating is

to pull the trash into every other row and irrigate in the other line. The trash keeps the surface soil moist, and increases the capillary connection between this line and the lines to which water has been applied. With a heavy soil, where we should expect lateral percolation to be slower than downward percolation, this practice may not prove very successful. Soil samples taken at Waipio show that 2 or 3 days after irrigation the moisture percentage in the furrow that was irrigated, and that which did not receive water, was practically identical.

Sugar Analysis and the Saccharimetric Scale.*

The Association of Official Agricultural Chemists held its annual convention in Washington, D. C., on November 17, 18 and 19. Matters pertaining to sugar occupied an important place on the program and took up the entire forenoon of the first day's session.

Referee Bryan's Report.

Mr. A. Hugh Bryan, referee on sugar, presented his report, divided into five parts. First, in regard to recommendations made by the former referee, Dr. C. A. Browne, he agreed with Browne that further study be given to the modifications proposed in 1916 for determining sucrose by acid and invertase inversion; to methods for the determination of small amounts of reducing sugars in the presence of sucrose; to the optical methods for estimating raffinose in beet products using enzyms for the hydrolysis. These three items he thought should be investigated in the carbohydrate laboratory of the Bureau of Chemistry. He suggested that the methods of determining copper by reduction of the oxide in alcoholic vapors be studied by workers outside of the Bureau.

In regard to matters for study advanced by Dr. W. D. Horne in 1917 the referee concluded that raw sugars might be mixed on a glass plate with a rolling pin or in a mortar with a pestle equally well; that in prescribing a minimum amount of lead in defecation, the regulations mean "just enough lead to cause a clear defecation"; that he personally preferred the average of a number of polariscopic readings to a reading substantiated by readings above and below the main reading; that polarizations of raw cane sugars made at temperatures other than 20° C. be corrected by the formula:

$$P20 = Pt + 0.0015\ (Pt-80)\ (to-20)$$

He accepted Horne's suggestions, however, that in case where the invert sugar is known the formula be $P20 = Pt + 0.0003P\ (t-20) - 0.00812L\ (t-20)$, where $P =$ polarization and $L =$ levulose (½ the invert sugar).

In conjunction with the former formula he gave a table of corrections for polarizations from 80 to 97 and for temperatures from 21° to 35° C. He advised against the use of the Beaumé scale.

* Facts About Sugar, Dec. 13, 1919, pp. 470, 471.

The American Polariscope.

In part two the referee discussed the proposed American-made polariscope, advocating the Jellet-Cornu polarizing system as simpler and cheaper, while being sufficiently sensitive for technical work. He discussed the much debated question of the normal weight of sugar to be used in polarizations, indicating a preference for the proposed change to 20 grams. He said a committee had been appointed by the American Chemical Society to get in touch with the various governments abroad with a view to arranging an international standard for the polariscope.

In part three was discussed the reestablishment of the 100° point on the saccharimetric scale by Bates and Jackson of the Bureau of Standards, with the consequent changes in the standard quartz plates tested in that institution. The referee strongly recommended that the corrected values be not employed until their accuracy shall have been agreed to internationally, basing his position on Herzfeld's question of the complete accuracy of the new value and the difficulties which some chemists may have in applying the corrections.

Part four dealt with temperature corrections to be applied in the polarization of cane sugars at temperatures other than 20° C., reference to which has been made above. More than 4000 comparative observations demonstrated the close approximation of the corrected polarizations to the tests made at the standard temperature. A chart of corrections was given covering all ordinary temperatures and polarizations.

Paper by Dr. Browne.

A paper on "The Attitude of the New York Sugar Trade Upon the New U. S. Bureau of Standards Value for Standardizing Saccharimeters," by C. A. Browne of the New York Sugar Trade Laboratory, followed the referee's report. Dr. Browne said:

"The question of the standardization value of normal quartz plates for saccharimeters which Mr. A. H. Bryan discusses in this year's referee's report is a matter of extreme importance, as the difference of 0.1 sugar degrees between the official standards of Berlin and Washington will mean a difference of over $1,000,000 in the valuation of sugars handled by the New York sugar trade. This conflict of opposing standards has already caused some uneasiness in the trade, and the matter has been carefully considered by the directors of the New York Sugar Trade Laboratory, who represent equally the buyers and sellers of raw sugar.

"The standard of graduation for the German or Ventzke scale which has been employed by the New York sugar trade up to the present time is the one which is being used by practically all members of the International Commission for Uniform Methods of Sugar Analysis, the methods of which are the official methods of the New York sugar trade. The directors of the New York Sugar Trade Laboratory, after careful consideration of the question, voted unanimously against the adoption of the new United States Bureau of Standards value for standardizing saccharimeters for the following reasons:

"(1) That this new United States Bureau of Standards value has been criti-

cized by European investigators, and until it has been confirmed by testing bureaus in other countries and has been agreed to internationally, it would be exceedingly unwise to adopt a value which might have to be changed again to something else.

Against Hasty Changes.

"The directors of the New York Sugar Trade Laboratory do not wish to make any departure in methods or standards unless the proposed changes have a fair prospect of permanency, especially in international transactions; otherwise the sugar trade will be continually subjected to disturbances of this kind.

"(2) Granting that there may be a slight error in the present German Standard, and even granting that the new United States Bureau of Standards value may be correct, the directors of the New York Sugar Trade Laboratory are of the opinion that no injustice is being done at present to the sellers of raw sugar for the reason that the minus error, due to scale graduation, is offset by an equal or greater error due to the volume of the lead precipitate in clarification.

"If a scale error exists it should by all means be corrected, and the true standardization value fixed by international agreement. When this scale error is corrected, the counter-balancing lead precipitate error should also be corrected either by dry lead defecation, as proposed by Horne, or by other accurate means.

"I might say in conclusion that this decision of the directors of the New York Sugar Trade Laboratory is in complete agreement with the opinion of Dr. Prinsen Geerligs of Holland and other European authorities."

Bates Discusses Report.

Dr. Frederick J. Bates, director of the Saccharimetric Division of the Bureau of Standards, read a paper comprehensively discussing certain features of the report of the Referee on Sugar. In regard to the Beaumé scale, he agreed that it would be more advantageous if the sugar industries would use the Brix scale, but since the Beaumé scale is so firmly intrenched it must be reckoned with, and in order to afford the most correct scale possible the Bureau had recalculated the scale on the specific gravity determinations of Plato, which are the most scientifically correct, had adopted the modulus 145 and had referred sugar solutions at 20° C. to water at 20° C. This scale he recommended to replace the two different Beaumé scales given in the provisional Methods of Analysis of the Association of Official Agricultural Chemists.

The Normal Weight Question.

Referring to the question of an international normal weight for sugar analysis, he called attention to the long struggle which culminated in doing away with the old German weight of 26.048 grams and the adoption by the International Sugar Commission of the 26-gram normal weight at the same time that 20° C. was adopted as the standard temperature. He showed that all the world but France uses this normal weight, and that France would probably be unwilling to adopt any new weight. He advocated the retention of the present weight,

both on account of the greater inherent accuracy of a large weight and the serious inconvenience that would come from any change.

In reference to the committee appointed by the American Chemical Society to arrange with foreign governments for an international sugar weight of 20 grams, the author wished to make the correction that this committee had merely been appointed to ascertain whether some European nations, particularly England and France, would be willing to adopt a 20-gram normal weight.

Opposes Referee's Conclusion.

In the matter of standardizing quartz plates by the Bureau of Standards, Bates showed that the difficulties feared by the referee would prove groundless through applying proportional fractions of the 100° point correction when polarizing solutions reading less than 100° S. As to foreign criticisms of the Bureau's redetermined 100° point, Bates stated that the only such criticism the Bureau is aware of is one by Herzfeld, "about 150 words in length, confined to a short discussion of several minor points involved in the preparation of the sugar used by the bureau of standards. Dr. Herzfeld merely conveys the idea of a possibility of the existence of a slight error due to these causes. He does not furnish the slightest proof that any error was made. On the contrary, all measurements and all contributary data developed since the determination of the constant by the Bureau of Standards have merely served to verify the correctness of the new value."

In view of the above he advised against the referee's recommendation that members sending quartz plates to the Bureau of Standards for standardization request that the Bureau certify on the old value of the 100° point, in place of the present corrected value, until this has been adopted internationally.

In the discussion which followed Dr. Bates' paper it was pointed out that the Bureau of Standards' work on the 100° point of the polariscope was conducted with the utmost precaution and the one criticism of it is merely a suggestion that some inversion of the pure sucrose used may have occurred. But no evidence of any such inversion is given, nor is it at all likely, as the sugar solutions used never were heated above 35° C.

The government will doubtless continue to employ the corrective value and it is important that all remaining errors of polarization, especially that elevation due to the volume of the lead precipitate be eliminated as soon as possible.

The following remarks were made by Dr. W. D. Horne, relative to recommendations proposed by Dr. A. Hugh Bryan, Referee on Sugar:

"In mixing sugar samples particular care should be taken to avoid excessive exposure to the air. Speed of work is of first importance; and avoidance of exposing thin layers of sugar may be helped by mixing in a mortar instead of on a plate.

"In cases where the invert sugar is known, more accurate results for individual samples may be obtained by using the formula

$$P20 = Pt. + 0.003P\ (t\text{-}20) - 0.00812L\ (t\text{-}20)$$

where $P =$ polarization and $L =$ levulose (½ the invert sugar).

"The Beaumé scale is so thoroughly intrenched in the industries that it will continue to be used and must be reckoned with. The Bureau of Standards' new

scale and table is of particular value, having the modulus 145, which is close to the average of those heretofore in use, is a round number, and has already been accepted by the Manufacturers' Association. The reference of sugar solution at 20° C. to water at 20° C. is also a great advantage."

Committee on Beaume Scale.

The chairman, Dr. Trobridge, appointed a committee consisting of W. D. Horne, chairman; Frederick Bates, R. E. Doolittle, Paul Rudnick and E. W. Magruder to report upon the most advisable steps to be taken in regard to the Beaumé scale. This committee submitted the following recommendation:

"That the Beaumé scale of the Bureau of Standards (Modulus 145) Table 31, Circular 44, U. S. Bureau of Standards, be adopted as the official Beaumé scale of the Association and that all Beaumé tables and references thereto which are not in accordance with this scale be eliminated from the methods of the Association; and further, that the Committee on Editing Methods of Analysis be authorized to make such changes in the text of the chapter on Saccharine Products as may be necessary to make this recommendation effective."

The chairman also appointed a committee composed of Frederick J. Bates, chairman; C. A. Browne and F. W. Zerban to consider and report upon the questions of the normal sugar weight and the standardization of quartz plates.

An important contribution on "The Double Polarization Method for the Estimation of Sucrose and the Evaluation of the Clerget Divisor" was presented by Dr. Richard F. Jackson and Miss Clara L. Gillis, both of the Bureau of Standards. This paper, which is a record of a very extensive investigation, will be given later in resumé.

[R. S. N.]

The Deterioration of Sugar.*

A Study of the Factors Causing Inversion—Infection by Bacteria and the Influences of Invertase Secreted by Micro-organisms.

By Nicholas Kopeloff and Lillian Kopeloff.†

The phenomenon of deterioration in sugar is now recognized to be a change from sucrose to invert sugar due to the invertase secreted by micro-organisms. In this connection, there have been the valuable contributions of Browne,[1] Owen[2] and others which have been concerned chiefly with the activities of bacteria. It was our purpose to pursue certain suggestions with regard to the importance of molds in the deterioration of sugar. With this end in view, an exhaustive survey

* Sugar, Nov., 1919, p. 578.
† Bacteriologists, Louisiana Experiment Station.
[1] Jour. Ind. Chem. 10 (1918), p. 178.
[2] La. Bul. 125, 146, 153, 162.

was made of the kinds of molds to be found in different sugars. There were three molds that occurred universally in the sugars examined, belonging to the *Aspergilli* which are frequently found and of wide distribution in soil, vegetable products of all kinds, water, etc. These molds were examined as to their power to deteriorate sugar by inoculating sterile sugars with them and analyzing the latter before and after incubation. It was found that these molds were capable of inducing very serious losses of sucrose in short time, if the conditions for their activity were favorable. However, deterioration also occurred where the moisture conditions were unfavorable. The physical evidence of growth is found in the development of threads of mycelia, and since enzymes were liberated during cellular activity, it is obvious that invertase is secreted in considerable amount. On the other hand, it was puzzling, indeed, to find evidence of enzyme activity where the molds were unable to grow. This led to a closer scrutiny of the inoculating material, which consisted of mold spores, and it was found that the mold spores (which represent a resting or inactive stage in the life history of molds) were capable of producing deterioration without germination. The conclusion was then irresistible and led to the discovery that mold spores contain the enzyme invertase, and that this enzyme was liberated by spores in sufficient quantity to effect deterioration. (A more detailed account may be found in Bulletin 166 of Louisiana Experiment Station.)

The proof that mold spores contained invertase was established as follows: Molds were grown in pure culture in Petri dishes and the spores floated off with water. This spore suspension was heated to 62.5° C. for 30 minutes, which was sufficient to kill the spores and prevent them from germinating, yet not high enough to injure the enzyme. Likewise, this treatment weakened the spore wall and permitted the invertase to diffuse out more readily. The spore suspension was then crushed with sterile sand and the resultant suspension containing a definite number of spores per cc. (which were acurately counted) was used as an inoculum in sugar solutions of 10 and 20 per cent concentration. Inversion was measured after 3 and 24 hours. Spores heated to 100° C. (which killed the enzyme) produced no inversion, proving that the above activity was enzymic in nature. Twenty cc. of the suspension produced twice the inversion that 10 cc. produced in both 10 and 20 per cent sugar solutions, and this, together with other enzyme laws observed, revealed the fact that the spores of these molds contained the enzyme invertase.

However, the fact that inversion was produced by mold spores in 10 and 20 per cent sugar solutions, is hardly sufficient justification for believing that inversion is similarly produced in sugar where the films surrounding the crystals and which support biological activity are so much more highly concentrated. To throw more light on this problem, sugar solutions ranging in concentration from 10 per cent up to saturation (in increments of 10 per cent) were inoculated with mold spores. It was found that at every concentration employed there was inversion, and the maximum invertase activity of these mold spores occurred between 50 and 60 per cent. This might explain some hitherto inexplicable cases of deterioration in solutions of such high concentration that they might have been assumed to be proof against deterioration. It was very interesting, also, to note in this connection that an increase in the number of spores at any

single concentration was responsible for increased inversion. This raised the query: how many mold spores are needed to produce inversion, at the saturation point, for example? It was found that the least number of spores of the most active mold *Aspergillus* Sydowi Bainier which were required was 5000 per gm. With the other two molds, *Aspergillus niger* and *Penicillium expansum,* between 50,000 and 110,000 spores per gm. were needed to accomplish the same results. Thus the evidence that mold spores alone are capable of deteriorating cane sugar was amply corroborated by the above data.

The significance of this phenomenon is worthy of serious attention since it must needs modify the prevailing conceptions regarding the deterioration of sugar. In other words, if a sugar is badly infected (and that implies the liberation of a considerable quantity of invertase from the spores), then this invertase will induce deterioration regardless of whether the moisture content which was hitherto believed to be the determining factor, is high or low. We have here a new and independent factor to consider in sugar deterioration, namely, the magnitude of the infection. This must be taken in conjunction with the other factor, moisture content, or more strictly speaking, moisture ratio.

That is to say, it has already been pointed out in the important researches of Browne[3] and Owen[4] that the important feature about a sugar is the relation between the moisture and the solids non-sucrose; that is

$$\frac{\text{Moisture}}{100 - \text{Polarization}} = \text{moisture ratio or factor of safety.}$$

This ratio should be less than 0.30 for a Cuban raw sugar to be regarded as safe from deterioration. To illustrate, let us suppose a 96° sugar has 1.14 per cent moisture. Its moisture ratio will be 0.28, and such a sugar will not be expected to deteriorate. On the other hand, a 96° sugar containing 1.36 per cent moisture will have a moisture ratio of 0.34 and will undoubtedly deteriorate on storage.

This empirical fact has received ample substantiation in the laboratory as well as in the field. Therefore it became necessary to investigate the influence of moisture ratio or factor of safety on deterioration by molds. In order to maintain an accurate control a series of laboratory sugars of definite moisture ratios were made by coating large "confectioner's crystals" of refined sugar with blackstrap molasses and sugar syrup (60° Brix) in varying proportions and purging in the centrifugal so that the sugars varied in moisture ratio from 0.08 to 0.20, while the liquid used to coat the crystals, which was inoculated separately in each case, varied in moisture ratio from 0.44 to 0.63. The sugars and molasses were analyzed before and after an incubation period of 4 months and the following conclusions noted:

A decrease in concentration of molasses was responsible for a progressive increase in deterioration where the inoculation of mold spores was appreciable. A decrease in concentration of films of laboratory-made sugars similarly inoculated caused an increase in deterioration after one and four months' incubation periods. This was obtained with moisture ratios less than 0.20 and *a priori* would be contradictory to the factor of safety rule heretofore mentioned, for it will be remembered that it was stated that sugars having moisture ratios

[3] Loc. cit.
[4] Loc. cit.

below 0.30 would not be expected to deteriorate. The explanation for this phenomenon will be discussed in another connection. Suffice it to say that this work with sugars and molasses corroborates the generalizations arrived at in the experiments with sugar solutions where deterioration was found to occur at high concentrations.

In the above work there was likewise evidence that an increase in inoculum was responsible for an increase in deterioration at any given concentration. This paved the way for a more exhaustive study which was concerned with the effect of the amount of inoculum and concentration on the deterioration of sugar by molds. In other words, there are two variable factors operating simultaneously in sugar deterioration, each of which has received attention more or less independently of the other, namely, moisture ratio and infection; but it was our purpose to vary them concomitantly. With this end in view, a series of laboratory sugars was prepared, as outlined above, having moisture ratios varying from 0.14 to 0.24. Each concentration was inoculated with mold spores at the rate of 100, 1,000, 10,000 and 100,000 per gm. respectively, and incubated for 1 and 5½ months periods. The results showed that an increase in inoculum was responsible for an increase in deterioration at any definite concentration, while, on the other hand, an increase in concentration with a definite inoculum was responsible for an increase in deterioration. And it became possible, therefore, to prepare a chart which would indicate whether deterioration would occur or not at any definite moisture ratio, providing the degree of infection were known. For example, 100 spores in a sugar with a moisture ratio of 0.16 produced no deterioration, but did produce deterioration in sugars having moisture ratios greater than 0.17. Again, 1000 spores per gm. failed to produce deterioration at a moisture ratio of 0.08, but did effect deterioration at 0.14. On the other hand, any sugar (within the limits noted) having an infection of 100,000 spores per gm. gave evidence of deterioration.

Next to an elimination of deterioration altogether, the most important commercial consideration is to predict the keeping quality of a sugar. From the standpoint of mold infection this may be done satisfactorily on the basis of the above data. In effect, this is equivalent to saying that if the polarization, moisture content and number of molds per gm. are known, it is possible to predict with a fair degree of confidence what deterioration, if any, will occur. Thus it becomes possible in a practical way to know whether or not certain cargoes of sugar may be kept and which must be used immediately, and in this way a serious economic loss may be avoided.

Finally, it becomes necessary to complete this phase of the problem by considering the importance of bacterial infection in deterioration. This has been done in an experiment just completed, in which 200-lb. bags of Cuban raw sugars were kept under normal storage conditions in the warehouse of the largest sugar factory in this country, and analyzed periodically both chemically and bacteriologically. The data need not be discussed in detail at this point, and it will be sufficient to note that it agrees very closely with the previous work mentioned where molds were employed. In other words, deterioration is the resultant of the two factors working simultaneously, moisture ratio and infection, and upon this basis it becomes possible to predict the keeping quality of sugars and thereby prevent economic losses.

[R. S. N.]

The Fuel Value of Alcohol.*

A Summary and Digest of Investigations Carried Out by the British Government —Importance of Suggestions to Sugar Men—Molasses Becomes More Valuable by Distillation into Power Alcohol.

By Dr. Walter Baunard.

With the contemplated increase in sugar production throughout the world, the question of utilizing the enormous quantities of molasses obtained as a by-product becomes of paramount importance. Especially is this the case in the West Indies, where considerable damage has been inflicted by the enforcement of prohibition in the United States, cutting off a large and ready market for rum and other distilled liquors, manufactured from molasses.

Hawaiian sugar planters and also planters in the Philippines have studied the alcohol production problem with considerable interest and have achieved some very encouraging results. It is, therefore, particularly timely at this period of stimulated cane sugar production, to examine the salient features of a comprehensive report of the British "Inter-department Committee" on the progress in Great Britain and British colonies, in the development of power alcohol.

In the British Empire there are vast existing and prospective sources of alcohol in the vegetable world, although in the United Kingdom itself production from these sources is now and is likely to remain small, but synthetic production in this country in considerable quantities, especially from coal and coke-oven gases, is promising.

As the price of alcohol for power and traction purposes, to which the name of "power alcohol" may be given, must be such as to enable it to compete with petrol, it is essential that all restrictions concerning its manufacture, storage, transport and distribution should be removed, so far as possible, consistent with safeguarding the revenue and preventing improper use, and that cheap denaturing should be facilitated.

The committee recommends that an organization should be established by the Government to initiate and supervise experimental and practical development work, at home and overseas, on the production and utilization of power alcohol and to report from time to time for public information on all scientific, technical and economic problems connected therewith. This organization should be permanent, have at its disposal the funds necessary for its investigations, be in close relation with the various governments of the Empire, and be so constituted as to be able to deal with alcohol in conjunction with other fuels which are or may become available as a source of power. * * *

The outstanding and fundamental attraction of alcohol motor-fuel as a substitute for any fuel necessary derived from coal or oil deposits lies in the fact that, on account of its chief sources being found in the vegetable world, supplies

* Sugar, Nov., 1919, p. 599 (abbreviated).

of raw material for its manufacture are being continuously renewed and are susceptible of great expansion without encroachment upon food supplies.

"We are of opinion," says the report, "that steps should be taken to insure increased production of power alcohol by the extended use of the vegetable matters from which it may be obtained. Important materials of this nature are: (1) Sugar-containing products, such as molasses, mahua flowers, sugar beet and mangolds; (2) starch or inulin-containing products, such as maize and other cereals, potatoes and artichokes, and (3) cellulose-containing products, such as peat, sulphite wood pulp lyes and wood.

"We have been unable to obtain comprehensive estimates of the world's production of molasses, although we have been furnished with statistics concerning the total quantities shipped from various countries, but there is evidence that large quantities produced in numerous sugar-growing areas are allowed to run to waste. * * *

"We are of opinion that, so far as vegetable sources of raw material for the manufacture of power alcohol are concerned, we must rely mainly, if indeed not entirely, on increased production in tropical and sub-tropical countries.

Denaturants and Denaturing.

"We have received a valuable report from the Government Chemist, Sir James J. Dobbie, upon practices usual in all countries to effect the denaturing of alcohol so that it shall be unfit for human consumption.

"We are of opinion that, when denaturing operations are carried out at any transport depot or yard, the existing regulations of the Board of Customs and Excise should be relaxed to permit the necessary volumetric mixings to be made in any suitable tank or other storage vessel, notwithstanding the fact that such vessel may still contain power alcohol previously denatured, provided that no refilling supplies for vehicles are drawn during the operations nor until after the new mixing is completed to the satisfaction of any officer of the Board in attendance.

"We recommend that, having regard to the exemption of home-produced benzol and shale motor-spirit from the motor-spirit tax (excise) power alcohol when produced in the United Kingdom be correspondingly exempted and that, having regard to the scope for earlier large production in the Empire overseas, importation of power alcohol be permitted free of duty.

"All sales and deliveries of power alcohol should be made on the basis of a certified percentage by volume of absolute ethyl alcohol, with a minimum of 90 per cent at a temperature of 62 degrees F.

"We are of the opinion that in denatured alcohol, or in admixtures of alcohol, benzol, ether, petrol, or the like, sold as power alcohol, the ratio of water to alcohol after admixture should not exceed one part by volume of water to nine parts by volume of alcohol measured at ordinary temperatures.

"We further consider that when benzol, ether, petrol, or the like, are mixed with alcohol in quantities in excess of those which may be legally required as partial denaturants the nature and amounts per cent by volume of such components should be plainly stated on the containers of such mixtures and on the contracts, sales notes, and invoices dealing therewith.

STATE ACTION TO DEVELOP PRODUCTION.

"We have, in a preceding paragraph, referred to the basic difference between alcohol on the one hand, and benzol, petrol, or other petroleum products on the other—a difference which has not as yet been properly appreciated—i. e., the fact that the chief raw materials for the production of the former can be renewed and are susceptible of great expansion, whilst those from which the latter are derived are limited to deposits, definite in extent, that cannot be renewed. Furthermore, as power alcohol is miscible with water in all proportions, its use affords greater safety from fire than does the employment of benzol, petrol or other petroleum products. We consider that these two factors should be regarded as sufficient grounds in themselves to justify State action in fostering the production and utilization of alcohol for power purposes.

"The work of the sections, so far as it has been carried, has been sufficient to show the complex and far-reaching character of the problem, and has convinced us that it can only be handled adequately by concerted Government action.

"We think that the development of the alcohol industry cannot be left entirely to the chances of private enterprise, individual research and the ordinary play of economic forces. No doubt in the long run, after a tedious process of trial and error, alcohol would find its proper place as a power fuel, but only with the maximum of friction, great fluctuations in price and serious waste of time, money and energy. The situation needs to be watched continuously and measures taken from time to time to ensure a smooth and rapid adjustment of supply to demand."

[R S. N.]

The Relation of Forestry to Agriculture.*

By WM. HILLEBRAND.

[In July, 1856, Dr. Wm. Hillebrand delivered the annual address before the Royal Hawaiian Agricultural Society on the subject of forestry, its significance to agriculture, and the importance of protecting the Hawaiian watershed forests. It is truly remarkable that this paper of Dr. Hillebrand's, prepared sixty-four years ago, is so highly pertinent to the forestry situation as it exists today in these Islands. In 1856 he explained the value of forests, the need of protecting them, and the wisdom of strengthening the native forests with introduced species. He told the whole story of the forestry question in such an able and interesting way that we are reprinting his address for the benefit of the readers of the Record.]

It has been customary at the anniversary meetings of our Society hitherto, to pronounce an unremitting eulogy on the calling which unites us here, and from which our Society has borrowed its name. Permit me, for once, to strike

* Extract from Transactions of the Royal Hawaiian Agricultural Society at its Sixth Annual Meeting, July, 1856.

in a different line and to abuse it. To abuse it? I hear you say: but then you are out of place! You ought not to have appeared here! Allow me to correct myself by saying, to abuse its *abuse*—to restrain it within its proper limits.

What is the object of agriculture? Why, to feed and clothe man; to still his hunger and thirst; to protect him from cold and heat, from rain and wind. To supply his wants, and procure his ease, this self-styled lord of creation goes to work without hesitation or scruple to remodel the features of nature, which an all-loving Providence has arranged so as to offer the means of existence to every one of its created beings, from the humblest moss and insect upwards to the highest developed animal. As if there were nothing worth existing beside him, he exterminates what does not administer to his wants or gratify his senses. Noble forests fall groaning under the relentless ax of the pioneer; myriads of modest little plants and weeds disappear under the burrowing edge of the ploughshare, to be replaced by a few kinds of social grasses called cereals, and some other plants and trees, from which he is accustomed to draw his sustenance. The aurox and buffalo, the elk and dam retreat to make room for the cow, the horse and sheep. So fully is he impressed with the propriety of his doings, that even his language outlaws by the opprobrious epithets of weed and vermin whatever poor being, with its innate instinct of self-preservation, interferes with the accomplishment of his preconceived mission. Where before forest and glade, swamp, meadow, lake, heath and river alternated in charming variety, now appears the level monotony of waving corn-fields or uniform pasture ground. Swamps are dried, lakes drained, rivers narrowed to their beds; the noble forest only finds a refuge on the inaccessible mountains, and with them flee away from the settlements of man, or disappear under his tramp, the lily of the fields, the merry songster of the woods. It hardly appears credible, and yet is true, that through the vast extent of China proper, save a few aquatic plants, not one herb is found indigenous to the country, unless cultivated by man. Such is the result of a few thousand years of continuous tillage of the soil. Presently call into operation one of those great political revolutions which sweep an industrious nation from the surface of the earth, or replace it by a barbarous one, the soil will cease to yield its harvests of corn, the rice-fields will dry, not to be replaced by the ancient forest, but to make room for the steppe, the desert. Let us follow up this reflection more in detail.

Once Centers of Civilization; Now Desert.

Setting aside the vexed question of the cradle of mankind, leaving it unsettled whether a paradise was on the table-land of Armenia, in the lovely vale of Kashmere, or near the terminus of the two mighty rivers of Central Asia, there can be no question that the first migrations of men took place towards the bottom land, between and around the Euphrates and Tigris, and along the shores of the Caspian Sea. There we see, at the earliest dawn of history, mighty empires flourish—not blooming into existence, but having already passed over that maturity of national development, where the rough virtues of the founders are softened into the refined enjoyment of life, under whose stimulus arts and sciences spring into existence. We actually find them in the last stage of degeneracy, where refinement dissolves itself into voluptuousness, and the effeminacy

Where the ridges of the Koolau Mountains have been protected from cattle an excellent forest cover exists. Photographed December, 1919.

of manners indicates the impending dissolution of the body politic. A succession of four great empires, one taking the place of the other, passes before our astonished eyes before even authenticated history begins; and yet the wondrous monuments, extracted by modern searchers from the bosom of the earth, lift from them the veil of myth, and divest doubt of its support. To this centre points the tradition of the Vedas, the Holy Writ of the Jews, and all historical evidence of the Caucasian tribes, as their origin. From there the man of Ur came with his flocks to settle, by the Lord's command, in Canaan; from there emerged the Pelasgi and Hellenes, destined to shed a never-dying lustre over the land of their choice; and later the Goths, Huns, Mongols; and last, the Turks, to crush the decaying empires of the west, either to invigorate their dying civil-

ization by a new stock, or to exterminate it. With them traveled their inseparable companions, the cereals, wheat and barley, already known and cultivated in Greece at the time of Homer—rye and oats completing their migration at a later time. In vain do botanists now search for the original home of those useful plants, disseminated though they are over the whole expanse of the globe, while all historical records trace back their origin to the starting point of man's migration. From where came the grape, which already tempted Noah's weakness; the fig, date and olive, intimately associated with patriarchal life; the peach, apricot and melon? The cherry, which first paraded in Lucullus's triumphal entry in Rome? The lemon, orange, mulberry, and many other of the

"It cannot be denied that in many places the domain of forest has been seriously encroached upon by man, and more by cattle."—Hillebrand, July, 1856.

A view in the Koolau Mountains, showing ridges denuded by cattle. Photographed December, 1919.

precious gifts of a bountiful Providence, which delight the senses of mortals? All testimony coincides that these countries were amongst the most favored of Nature's creation, swelling under exuberant prolificness. From the remotest times of antiquity man felt attracted towards these regions, and generation followed upon generation, populous cities were destroyed, to be superseded by others more splendid. As late as the time of Alexander, the great conqueror's historian tells us of the country between the Tigris and Euphrates, that "its soil is so rich and fecund, that they say the cattle must be driven off from time to time, lest they perish from surfeit." Compare with this the reports of recent travelers, who in these very regions have to wend their toilsome way over dreary deserts for weeks together, and in what few spots they find the country looking green and blooming on both sides of the river, have to limit it by the addition, that the fertility extends only a few miles inland, but beyond all is a sandy

A steep slope protected and well covered.

desert. "Most striking in this part of Mesopotamia," says Ida Pfeiffer, "is the entire want of trees; for the last five days I have not seen one, and I believe there must be many people who have never seen any in their lives. There were tracts of twenty or thirty miles where there was not so much as a shrub, though there is no want of (running) water, for no day passed in which we did not cross one or two rivers, large or small." These remarks refer to the cities of the old Assyrian and Babylonian empires. A few degrees farther east the forty marble columns, time out-lasting monuments of the royal city of Persepolis, loom as melancholy land-marks, at the foot of bleak hills, out of a dreary desert. Not more than one-tenth of the whole area of Persia is at present available for cultivation; the rest consists of sand and bare rocks.

The Land of Milk and Honey Is No More.

Turn your eyes to the west—Palestine is no more the land of Canaan, which

A steep slope, denuded by cattle. Photographed December, 1919.

flowed with milk and honey; the physiognomy of neighboring Arabia seems to have extended over its eastern half. The waters of Merom make room for rice-fields during three-fourths of the year; and the Jordan, the only river of Palestine whose waters flow during the whole year, leaves a dry bed in summer between Merom and Chinnereth, and near the Dead Sea, at the terminus of its course, its depth sinks to three feet. The cedars of Lebanon are thinned; the site of Jericho, the City of Palms, is now occupied by the movable tent of the wandering Bedouin, palms and ruins are missing. Mount Carmel alone, with its thickly-wooded slopes and densely-covered valleys, in which myriads of limpid brooks rill through a luxuriant verdure, seems to redeem the old renown of the Promised Land; while the plain of Sharon and the hilly country of Samaria only clothe themselves during the few rainy months in their former splendor. It is not Moslem indolence alone that has to account for these changes. To finish the picture with the poetical words of the illustrious Schleiden: "No Pythagoras in Egypt need

now forbid his disciples the use of the lotus bean; for the soil has lost the power of producing it. The wine of Mendes and Mareotis, which cheered the guests of Cleopatra, and was found worthy the praise of Horace—it has ceased to grow. The assassin will no longer find concealment in the sacred pine forest of Poseidon, to lay in wait for the bard that hurries to the Olympian games, for the pinia has long ago fled from the approaching climate of the desert to the heights of the Arcadian peaks. Where are now the pastures, where the fields around the sacred mansion of Dardanus, which, along the foot of moisture-dripping Mount Ida, fed three thousand mares? Who would not speak of a Xanthus impelling its waves? Who would realize a horse-feeding Argos?"

One simple observation is significant. The clover, which requires a moist climate for its cultivation, has gradually receded from Greece to Italy, and from there to Southern Germany, where already now it begins to be sensibly affected by the increasing drought of summer. Perhaps another singular fact may find its explanation here: Asia, the greatest continent, has a lesser number of indigenous species of plants than Europe.

Germany Eighteen Hundred Years Ago and Now.

Let us look at the other side of the picture. Eighteen hundred years ago my goodly fatherland, Germany, received hard names from Tacitus: *Terra in universum aut silvis horrida, aut paludibus foeda, frugiferarum arborum impatiens*: a country either bristling with dark forests or infected by ugly morasses; swampy on one end and stormy on the other. No fruit trees, he tells us, could grow there. The great rivers Rhine and Danube were every winter covered with so solid a crust of ice, that the barbarians would make their predatory inroads in neighboring districts by passing over them with their cavalry, wagons and material. The elk and reindeer, now confined to the Polar regions, as we learn by Caesar, swarmed over the vast extent of the Hercynian forest. All descriptions of those times would convey the impression, as if it had been a country fit to be inhabited only by brutes and savages, who lived on acorns and would get drunk on barley meal. The parts of Germany with which the Romans at that time had become best acquainted, were the regions along the borders of the Rhine and Danube.

Now place yourself in imagination, on a sunny May day, upon the hill of Schloss Johannisberg, and let your eyes pass slowly in a circle around you. Is that the same country described by the Roman? Is this the sun that shone on his nation's legions? A checkered cloth of vineyard, corn-field and orchard seems to be spread over the undulating plain, only to be interrupted by handsome villages, flourishing cities, and the parks of the wealthy filled with exotic plants. Take a jaunt over the Bergstrasse, along the foot of the Odenwald; for some sixty English miles you walk through a forest—not of sombre oak and pine, but of fruit trees of every description, the scent of whose blossoms pervades the air with fragrance and fills the heart with delight. In summer shiploads of cherries float down the river; and during the vintage, in the fall of the year, the whole population abandons its habitual occupation to cull grapes and press them in vats, amidst a never-ending frenzy of mirth and gaiety. This is the country where neither cherry nor grape would ripen in Tacitus's time. Good

wine is now made in Germany as far north as fifty-one degrees. As late as the time of Strabo it was thought that the grape would not ripen north of the Cevennes. At the present day the finest peaches are raised at Montreuil, near Paris, and France is considered the greatest wine-producing country of the world.

The Revolution Caused by Civilization.

I have tried to delineate in a few general sketches the two phases of the revolution which civilization—for this I take to be equivalent with agriculture—produces on the surface of the globe. In the first an almost uninhabitable country, the perennial mists of which hardly allowed the sun's rays to touch the ground, has been converted into a lovely garden; in the second, the happiest regions of the earth have been transformed into sunburnt deserts. If we ask for the immediate cause of these changes, we are, besides a few accessory agencies, led to the disappearance of the original perennial vegetation, and more especially the trees. Wherever the hardy pioneer fixes his fireplace, his first work is to lay the ax on the noble king of the forest. He chooses woodland in preference, unless rich alluvial bottom land be at hand, because the organic decay which has gone on for centuries under its shadowy roof, has enriched the soil with humus, has mellowed the stiff clay, or rendered more compact the light sand. What then is the effect of forests upon soil, upon climate and vegetation?

The Two Evils Following Waste of Forest.

As long ago as 1804, Alex. Von Humboldt in his "Voyage aux Regions Equinoctioux," warned that the waste of forests entailed two evils on the following generation: a want of fuel, and a deficiency of water. The reality of the first is self-evident; the second, although perhaps vaguely felt by any general observer of Nature, was first by him enunciated dogmatically. Of course, a statement which, if substantiated, entailed such important consequences, was well worthy to arouse a general attention; and since it was first promulgated up to this time, such a mass of evidence has been accumulated that the theory may well be said to have become converted into a doctrine.

Relation of Forests to Water Supply.

The necessary supply of water to a country is furnished by rivers and rain; or, more generally speaking, by atmospheric deposit. A falling off in the supply by the former source can take place without a corresponding diminution of the latter, although a decrease of rain will always be followed by a scarcity of running water. Springs and sources originate on the same principle upon which artesian wells are constructed. The water, precipitated from the atmosphere as rain, dew, etc., is taken up by the upper permeable layers of the soil, filters through them, follows rents or fissures in the rocks until a solid rock or stiff layer of loam oppose its further progress, and oblige it to follow the declivities of the same; passing by lateral fissures, or heaved up by the pressure of the following waters, it reaches the surface as spring or source. Supposing a sufficient quantity of rain to fall, the amount of running water may still be affected by two causes: a quick evaporation on the surface, or

undue hardness and resistance of the soil. How from a surface exposed openly to the unmitigated rays of the sun, a great waste of deposited moisture should take place by evaporation, needs no further commentary; nor will any one who takes a look at the bleak slopes of the steep basaltic hills back of our village, find difficulty to conceive how a heavy dashing rain will wash away the minutest particle of soil, as soon as it forms from the disintegration of the rock. In the same manner the light, movable humus soil, left after the clearing of a forest, will, when situated on a declivity, be swept away as soon as the firm interlacing network of roots and rootlets has lost its vitality, and no leafy roof moderates the force of the dashing torrent. In both instances an impermeable stratum remains on or near the surface, and the watery deposit, when small, will return to the atmosphere by evaporation; or when large, sweep down in torrents, overfill the beds of rivers, and pervert, by sudden inundations, into a curse what ought to be a blessing to man. A forest will not only, by its cool shade, lessen greatly the evaporation and retain what evaporates under its vault, but its canopy will also moderate the impetus of the falling drops and distribute its descent over a longer space of time. Besides, the humus layer forming its floor, by virtue of its great hygroscopic capacity, retains for a long time the imbibed liquid, and thereby regulates the flow of the rivers, preventing their sudden overflowing and yielding them food long after the rain has ceased. The inundations, of late so frequent, of the river Oder, in its lower course, are attributed by experts to the waste of forests in the mining districts of Upper Silisia, while it is stated that the planting with trees of the formerly naked slopes of the French Alps has done away with the torrential floods which formerly devastated the lower valleys. With regard to the obstacles offered by a thick forest to evaporation, a traveler in South America says: "In the forests the humidity is constant; it exists long after the rainy season has passed; and the roads that are opened through them remain through the whole year deeply covered with mire. The only means known of keeping the forest ways dry, is to give them a width of from 260 to 330 feet; that is to say, to clear the country in their course."

Deficiency of Water Follows Forest Destruction.

A remarkable instance of how running water diminished by mere evaporation, without falling off, even with the increase of the yearly quantity of rain, is related to us by Boussingault. The metalliferous mountain of Marmato is situated in the province of Papayan, in the midst of immense forests. The stream along which the mining works are established is formed by the junction of several small rivulets, taking their rise in the tableland of San Jorge, which overlooks the establishment, and is thickly wooded. When Boussingault visited the place in 1826, he found only a few miserable cabins inhabited by negroes, but on his return in 1830 the country had the most flourishing appearance. It was covered with workshops, had a foundry for gold, machinery for grinding and amalgamating the ores, and a population of nearly 3000 inhabitants. It may be imagined that during these four years an immense quantity of timber had been cut down, not only for the construction of machinery and houses, but as fuel and for manufacturing of charcoal. The felling had princi-

"Of all the destroying influences man brings to bear on nature, cattle is the worst."—Hillebrand, July, 1856. A gulch denuded by cattle, Koolau Mountains, Oahu. Photographed December, 1919.

pally gone on on the tableland of San Jorge. But scarcely had two years elapsed before a notable diminution of the water in the stream was noticed. The volume of the water had been measured by the work done by the machinery, and actual gauging at different times showed the progressive diminution of the water. The question assumed a serious aspect, because at Marmato any diminution in the quantity of water, which is the moving power, would of course be attended with a proportionate diminution in the quantity of gold produced. As soon as the diminution of the stream was ascertained, a rain gauge was set up, and in the course of the second year of observation a larger quantity of rain was gauged than in the first year, although the clearing had gone on, still there was no appreciable increase in the size of the running stream. A very similar observation has been made on the Island of Ascension, where an excellent spring

at the foot of a mountain originally covered with wood, dried up when this was cut down, but reappeared in former abundance when the mountain was planted again. Such remarkable effects, arising from the operation of causes limited to narrow localities, cannot be attributed to a diminution of rain. In the first cited instance there was even in one year an uncommonly large fall of rain—undoubtedly accidental. Undue evaporation only can be assumed as the sufficient cause.

The Theory of Condensation.

Let us now see how forests may affect the absolute quantity of rain, or precipitate of atmospheric moisture. From the surface of the water and the exhalation of plants and animals a constant evaporation of watery vapor is carried on. The vapor, consisting of an aggregation of small vesicles, according to its lesser specific gravity, rises steadily from the lower and warmer to the upper and colder strata of the atmosphere. Every gas, under a given temperature, can only take up a certain maximum of moisture; when it has reached that, we call it saturated. When it is saturated, any addition of vapor will be condensed again to water. The lower strata of the atmosphere, being warmer than the upper ones, take up a larger quantity than the latter; consequently these will be saturated, while the former still retain capacity to take up more. As soon as this point is reached, all surplus in the upper regions will have the effect to coalesce those countless invisible vesicles in a lesser number of larger ones, whereby they become visible to the eye as clouds. The more this condensation proceeds, the heavier the vesicles will become, until their specific gravity exceeds that of the atmospheric air, when they fall down. In their downward course they steadily grow by appropriating to themselves the surplus of the lower strata, which, by their contact, are suddenly cooled down beyond their saturation point, and reach the earth as rain. Not unfrequently it happens—and we in Honolulu may witness the sight almost daily—that when a rain-cloud has to pass, in descending through a drier stratum of atmosphere, whose temperature is considerably higher than its own, it dissolves again by evaporation and disappears. The same effect, of course, is produced by dry and warm winds. But any strong wind may, for a limited locality, become a cause of disturbance, inasmuch as its impetus will overcome the specific gravity of a cloud. From these preliminary considerations it seems to be a lawful deduction, that any causes which increase the moisture of the atmosphere in general, and lessens the temperature and dryness of the lower strata, will augment the fall of rain. Have forests a tendency in either of these ways?

How Forests Increase Rain.

The great source of atmospheric moisture is the vast expanse of flowing and standing water; for an insular climate it is the paramount one, against which all other sources sink into insignificancy. But different is it with vast tracts of wooded land in the interior of a continent, particularly where a high wall of mountains forms a barrier to the sea wind. There the amount of moisture exhaled in the vegetating process will play an important part; and, indeed, Humboldt considers it as the great factor by which forests increase rain.

Far different, however, is it with regard to the second question. Do forests

contribute to cool the lower atmosphere? A child knows that a shade affords coolness by intercepting the rays of the sun, and any one superficially acquainted with the laws of natural philosophy can tell you that a dark-colored surface, as the sapgreen of leaves, imbibes the rays of caloric, while a light one, like sand or limestone, reflects them, and thereby heats the ambient gaseous medium. The imbibed heat again is spent in hastening the evaporation of the water contained in the leaves. But in evaporation of liquid a considerable amount of caloric is bound as latent heat, which is abstracted from the ambient medium. Pour a drop of ether on your hand and you will soon perceive the cooling effect of its transition to gas. Similarly the exhalation of plants. Thus the forests may operate in a variety of ways towards reducing the temperature of the lower strata of atmosphere, and therewith their point of saturation.

Origination of Dew and Its Relation to Vegetation.

But these are not the only, perhaps not even the principal, ways in which forests contribute to fix the atmospheric moisture. Let us consider how dew originates. A general property of all bodies is that of radiation of heat. A body will constantly emit heat to the surrounding mediums, and only keep up a steady temperature, when it receives as much as it gives off. Different bodies possess this quality in a different degree: gases and atmospheric air have least of it, most of all organic substances, particularly such as combine greatest surface with least bulk, as cotton, wool, feathers. During a clear and calm night, when the great generator of caloric, the sun, has sunk below the horizon, and no other source of heat is left but the imperceptible one of the proper heat of the earth, all bodies will steadily lose heat by radiation towards the upper regions of the atmosphere, for these being greatly cooler than the lower ones will abstract heat without rendering an equivalent. Any fast-cooling body will, by lowering the saturation point of the surrounding atmosphere, precipitate the vapory moisture in it; a principle upon whose application Daniel's hygrometer is constructed, and upon which rests the formation of dew. Dew is only observed during calm and serene nights; whatever obstructs the free communication of the lower and upper regions of the atmosphere, as clouds or smoke, prevents the formation of dew, because it lessens the radiation towards the upper atmosphere. A wind likewise will interfere with the formation, as it brings warmer air in contact with the radiating body. You all will be aware that you enjoy the most refreshing sleep during a calm night with an open starlit sky, while the air becomes sultry and oppressive when the heaven is clouded. Grass and leaves being in themselves strong radiators will cool the more rapidly, as they have only a slender communication with the earth, by which the acquired sun heat of the latter might be conveyed to them. Thus a thermometer laid on the bare ground will stand from ten to fifteen degrees higher than one suspended between the grass. For this reason grass and trees are covered with dew, when rock and stone are not, and are dripping when these are moist. In tropical countries this phenomenon must necessarily appear more striking on account of the greater diffusion of watery vapor at elevated temperatures. "In the bivouac on the edge of the forest of Cauca, between the fourth and fifth of July," says Boussingault, "the night was magnificent; nevertheless, in the forest,

Cover of Kukui and ginger, the ginger being an introduced species. Photographed December, 1919.

which began at the distance of a few yards from our encampment, it rained abundantly; by the light of the unclouded moon we could see the water running from the branches." Those of you who frequently have to repair to our mountain woods know that if they go before the sun has moved near its meridian they are likely to have wet feet, even though it had not rained during the night, and the open plains appear dry.

Process of Emanation in a Forest.

What I have said with regard to emanation of heat has only reference to the nightly formation of dew, which, although of less consequence for most countries, plays a most important part in countries where it hardly ever rains, as in the district between Payta and Lima. Let us, however, carry our considera-

tion a little further. If we apply the law of emanation to a large tree, we find that free radiation can only proceed from the crown of the tree. The lower branches cannot radiate towards the sky, as the upper ones act in the manner of a screen; but in the measure, as the leaves of the crown cool off, the next lower ones will emit heat to them, which these will again send off towards the sky. The same process is thus continued progressively from all the upper to the lower branches, and the amount of caloric withdrawn from a given area grows in progression. Of course, the air circulating between the leaves participates in the loss. In this manner Humboldt has calculated that a tree which presents a horizontal section of not more than one hundred and twenty or one hundred and thirty square feet, actually influences the cooling of the atmosphere by an extent of surface several thousand times more extensive than this section. What a condensing power is thus created in a tropical forest! Aside by this *a priori* deduction set the fact, that in wooded tropical regions about seventy per cent of the annual average of rain falls during the night, and you will find the connection between cause and effect immediate. The effect of such an amount of cooling down, it is easily conceived, cannot be limited to the night alone, but must necessarily extend at least over a great part of the day. Thus we may contend with full reason that forests cool down the average temperature of a country, and thereby contribute powerfully to the condensation of atmospheric moisture in the shape of rain or dew.

It was long maintained by many observers that forests could have no influence on increasing the annual quantity of rain, however much they might contribute, by lessening evaporation, to keep up a due amount of running water, or to regulate the fall of rain over the different seasons. The aggregate amount of rain falling on our globe, or even within defined zones, in the course of a year, probably does not vary as long as the sun continues to send us every year the same amount of heat. But certain localities may be enabled to appropriate to themselves an uncommonly large proportion; and perhaps there prevails even in the grand chain of cause and effect in the universe, the law of commerce, that the consumption regulates the production. The quicker the atmosphere is debarrassed of its load, the sooner it will charge again. Be this as it may, experience seems to have decided the fact, that for given localities forests increase the mean annual quantity of rain.

St. Helena, an Example of Increase of Rainfall Due to Forests.

In St. Helena, where extensive plantations have been carried on for a number of years, careful observations show that the yearly average of rain has almost doubled since the time that Napoleon was a prisoner in Longwood, and the torrential floods, formerly so common, have not occurred for the last nine years. The most remarkable instance in point is probably the lake Aragua in Venezuela. This large inland lake, bounded on all sides by high ranges of mountains, which pour in their waters, and at the same time debar its outlet, was seen and accurately described towards the end of the sixteenth century by Oviedo, who says that the town of Valencia was founded 1555, at the distance of half a league, or one and a quarter English miles, from the shore. When Humboldt visited the valley in

1800, he found the town three and a quarter miles removed from its banks. What formerly had been described as isles or shoals, were now main land or peninsula, and new isles had arisen from under the surface of the water. Rich bottom lands had been gained by the retrocession of the water, which were covered with flourishing plantations of cotton, sugar, and cacao. The whole valley bore the loveliest aspect, covered as it was with the work of industry and labor. Even the slopes of the hills had been stripped of their trees and transformed into corn-fields. The retrogression of the lake had been noticed by the inhabitants with astonishment, and was generally ascribed to a subterranean outlet. Humboldt's genius divined the true cause, and from it threw out the warning with which I introduced the present investigation. Some time after his leave the war of liberation broke out, slavery was abolished, hands and capital were drawn off for many years, and the flourishing plantations went to ruin. The maize and corn-fields on the slopes gave way again to brushwood and forest, which sprang up quickly, with that exuberance proper to the rich gem of the tropics. Twenty-five years after Humboldt, Boussingault visited the place, and now found that the water of the lake, instead of continuing to recede, had risen perceptibly, submerging the isles of new formation and swamping the cotton fields on the rich bottom lands.

Instances of Rainfall Diminution Induced by Forest Destruction.

Lakes without exit which receive the waters of hill-bound basins of considerable extent, are certainly the best test gauges to apply to the present question. Observations in regard to them are manifold in all continents. So Boussingault infers from numerous data, that the two lakes of Ubaté and Zimiyaca in New Grenada, two centuries ago, only formed one sheet of water. The country round them has since been cleared of woods for the supply of fuel for two neighboring salt springs. And as a contrast, he remarks the lake of Quilatoa, not far from the former, which was exactly measured by Condamine in 1738, was found by him in the same limits in 1831. This lake is situated at an elevation of 13,000 feet, uninfluenced by the effects of agriculture and vegetation. Similar are the conclusions Saussere arrived at from a careful study of the lakes of Neufchatel and Brienne, and Morat, and those of Humboldt with regard to those of Southern Siberia. Hindostan also offers some direct instances to the point. On the high tableland of the Dekan the annual rainfall averages from 60 to 200 inches; but in some of its districts, which have been extensively robbed of forests, precise observations show only a fall of 10 to 25 inches. The reckless destruction of the spice trees on some of the Banda Islands, prompted by Dutch avarice, has converted these gems of the sea into as many bare rocks. From the Cape de Verd Islands sounds this moment a cry of distress. The usual drought which since the destruction of the woods befall these now to rock and sand reduced islands (for three successive years they have had no rain) have again produced one of their regular effects. Famine and disease had slaughtered already six thousand of their wretched inhabitants before the beginning of April, and two thousand more, so says the proclamation of the Portuguese governor, would fall by the scourge before the end of summer unless charity from abroad sent relief. I could multiply my illustrations, but shall

Along a ditch trail, Koolau Mountains, Oahu, showing good forest cover. Photographed December, 1919.

conclude with calling attention to the state of climate on the Pacific coast of South America, from the Gulf of Darien down the coast of New Grenada and Ecuador, in contrast to the immediately following coast of Peru. Both are, so far as mean annual temperature, proximity to the sea and high mountains, prevailing winds, etc., are concerned, similarly situated; but the former is densely covered with forests, while the latter is remarkable for its total absence of the same. Now, what is the result? The former is supplied abundantly with rain; in the province of Chocos it rains almost incessantly, while in Payta it has not rained once in seventeen years. One tract of the Peruvian coast, "Sechura," derives its name from this circumstance. It is well known that the inhabitants of Lima consider roofs a superfluous incumbrance to their houses.

I might still enlarge upon the fertilizing agency of forests in fixing the

carbon of the atmosphere, thereby supplying the soil with humus, or the great superiority of rain over running water, inasmuch as the former precipitates, in the shape of carbonate of ammonia, the nitrogen so indispensable to the most nutritious parts of a plant. I could demonstrate to you that the mud which now threatens to fill your harbor, and exposes you to the heavy expense of dredging it, would for the greatest part have been retained on the inclined planes of your valleys, to become as useful as it is now annoying, by the presence of trees, if I did not fear to draw out to undue length my present discourse.

What Is the Golden Middle Road?

Thus the testimony in support of our main question has accumulated so as to raise it beyond all controversy. Extensive forests will render the climate cool and wet, while absence of them imparts to it dryness and warmth. The former engender a multitude of brooks and rivers, swamps and lakes, and envelop the surface in mists and fog; the rains are equally distributed over the seasons; the difference between the mean temperature of summer and winter is small; agriculture will only prosper where the aggregate amount of summer heat is large enough to mature its products—that is, in lower latitudes. The latter condition gives to the country a clear unclouded sky; the difference between summer and winter temperature becomes excessive; the winters are colder, the summers warmer; the rains either disappear or are limited to one short season, in which they fall with extraordinary violence and overflow the generally dry beds of the streams; vegetation is suspended during a greater part of the warm season. Neither of these conditions of climate is particularly favorable to agriculture. Here, as everywhere, the golden middle road is the best. Clear enough ground to allow the sun to exercise an impression sufficient to accumulate during the vegetating season heat enough to mature the seed and fruit, but retain trees in sufficient number to attract and economize the necessary supply of moisture, indispensable to all organic beings. Now it will be clear how in one place agriculture will appear to have changed a wilderness into a lovely garden, swelling with the richest offerings of Nature's choicest gifts; while in another the arid sand of the desert settles down where reckless selfishness of man, in its steady combat with Nature, succeeded in routing the latter. There we see the first stage, here the second of the grand revolution. What a terrible warning! What an amount of wholesome instruction is contained in this reflection!

The Selfishness of Man in the Wanton Destruction of Nature.

No one has more forcibly expressed these sentiments than the venerable veteran amongst the eminent naturalists of our age, Elias Fries, of Lund, in Sweden: "A broad border of devastated land follows progressively the steps of cultivation. With its extension its center and cradle dies, and only in the circumference are found its green branches. But it is not impossible—difficult only for man—to repair the damage he has inflicted without renouncing the blessings of cultivation itself. He is destined to be the Lord of creation. It is true thistles and thorns, ugly and venemous plants, poignantly called dunghill

plants by botanists, trace the path which man has traveled hitherto over the earth. Before him lies primitive nature in her wild but sublime beauty; behind him he leaves the desert, an unseemly, exhausted land. For childish love of destruction, or improvident waste of the vegetable treasures, have annihilated the character of nature, and, frightened, man himself flees from the scene of his misdeeds, leaving to savage tribes or the wild beast the degraded earth, as long as another spot allures him in virgin beauty. Here also, seeking selfishly his own gain, and following aware or unaware the most abominable principle, the most execrable immorality ever enunciated, *'apris moi le deluge,'* he begins anew his work of destruction. Thus the moving cultivation left the East, and earlier perhaps the desert; spoiled of its vestments, thus it abandoned the whilom beautiful Greece to savage hordes. Thus this conquest rolls with stupendous celertiy from east to west, through America; and there now already the planter leaves the exhausted soil of the eastern shores, the climate rendered unproductive by the annihilation of the forests, to imitate in the far west a similar revolution. But we see also that noble men, of truly cultivated minds, commence to raise their warning voice to begin on a small scale the second more laborious task, to restore Nature to her strength and vigor. Truly, this undertaking is at present feeble, and disappears in view of the great object to be attained, but it preserves the faith in the destiny of man and in his power to fulfill it. In future man will and must succeed to free Nature, while controlling, guiding and protecting her, from the tyrannical slavery to which now he debases her, and in which he can only maintain her by a never-ending struggle against the eternally rebellious. In the dim distance of the future we see a reign of peace and beauty on earth and in nature, but before man reaches it he will have to take many lessons from nature, and before all, emancipate himself from the chains of egotism."

Education in Forestation.

Indeed, the attention of scientific men and governments has been seriously aroused to the importance of the subject. More than forty years the maintenance of existing and nursery of new forests has been a prominent care of the German states; not so much at first from a proper understanding of the enunciated principles as from the necessity to keep up a due supply of fuel and timber. At present, however, these principles are fully appreciated, and the extensive plantations on naked hill ranges or unproductive plains give ample evidence of it. A special branch of officers is appointed by governments, municipalities, and large land owners, to watch over the interests of the forest; and special schools, distinct from those for agriculture, are established and liberally endowed for instruction of pupils who devote themselves to this particular study. In Germany the schools of Tharand and Hohenheim, in connection with the name of a Cotta and Hartung, have signalized themselves. At a meeting of the British Association at Ipswich, in 1852, the subject was profoundly discussed and its importance seriously pressed on the attention of the English public. In Hindostan the East India Company has taken vigorous steps to inhibit the destruction carried on formerly, and to fill up by plantations on a large scale the void produced by them.

Application of the Lessons of History to Hawaii.

So far, gentlemen, I have entertained you at great length of time with the disastrous influence of civilization upon climate and nature at large. But where, will you ask, is the application to our young country, where civilization only dates since yesterday; where agriculture is just beginning to impress upon it the stamp of refinement and embellishment, which you before described as its first stage? I will admit for a moment the validity of your objection. In that case my answer is this: if there are no faults and wrong doings of men that need correcting, it is the short-comings of nature which I should wish to see assisted and hurried on. To speak more plainly, the gist of my foregoing remarks is, that a certain amount of perennial, high and dense vegetation is necessary to secure the interests of agriculture on a permanent basis; that in other countries this condition existed but has been destroyed by man, but that our country has not reached a sufficiently advanced age, wherein nature might have accomplished its great end of covering the earth with vitalized beings, which are necessary to complete the great cycle of action and reaction on each other of earth and atmosphere.

It may safely be presumed that when the mighty fiat first sounded over the great expanse of land and water, the ocean quietly rolled its billows over the spot where now our archipelago has risen. When those immense forests of Calamites, Sigillarias and Lepidodendrons accumulated in the bottom lands of receding waters, to be submerged by the flood; which again receding, left their debris covered with a deposit, thus again forming the ground-floor for a new vegetation, only to be buried and to resurge by the same process—that epoch is probably far anterior to the birth of our Islands, which, besides the immediate compounds of Vulcan's subterranean fires, do not present to the geologist but formations of the latest epoch. There are even reasons to suppose that organic life began here a long time after the last configuration of the earth-crust, after it had made considerable advance in other parts of the globe. Yet our Islands have a creation of their own, even peculiarly their own, from which starting nature began in her slow progress to cover every spot, as it became inhabitable for organized beings.

The Migration of Plants to the Islands.

Soon the waves scudded along from distant regions a stray cocoa-nut, a hard-shelled bean or pandanus seed; the winds carried over the almost microscopical spores of cryptogamous plants and seeds endowed with wings or parachutes (although the smaller number of plants with this kind of seed in common with neighboring countries might make us infer, *a priori,* our great remoteness from them), birds dropped a small amylaceous or grass seed, entangled in their feathers elsewhere; and last of all came man, bringing with him the means of his sustenance—probably the banana and bread-fruit. But man, after having been deposited here, was cut off from his anterior home, and therefore with, or soon after, his arrival, his agency ceased. Only with the appearance of the white man another era dawned; he at once bound this isolated group to the five continents, and established a highway on which what

lived or breathed in distant regions might wend its way hither. What to accomplish, nature alone in her slow but steady way would have required hundreds of years, the intellectual, analyzing, and combining power of man, penetrating and imitating her own laws, may do in as many decenniums, not indeed on such a gigantic scale as nature is wont to do it, for with all his application and energy his works will ever remain dwarfish when compared with her immense powers; but on a small scene of action, when his works are favored by the forces of nature, he can make a great impression on the physiognomy of a country.

Wherever the white man goes he carries with him his accustomed means of sustenance; the cereals follow him like his shadow. With the cereals he spreads involuntarily the seeds of weeds whose favored habitat is with them. Culinary vegetables, fruit trees, ornamental plants follow next, a great many of which soon acclimate and become naturalized. Many wild plants stick to his steps, as it were, as an indispensable accessory, although neither utilitarian reasons, nor particular aptitude for transmissibility in the seed, account for it. Thus the plantain, *plantago major,* invariably sprung up where the settler in North America raised his cottage. The Indians still call it the white man's footstep. It has followed him here. Another plant growing around you, the thorn apple, St. James' weed, *Datura Stramon,* originally an East Indian plant, spread from there with the migration of the Gypsies over Asia and Europe; from Europe the white man carried it to America, Africa, and Australia. During the great war movements of 1814 and 1815 it was observed that a *Siberian Corispermum* sprung up wherever the Cossacks had pitched their tents in Germany. From America the *Erigeron canadens* spread over Europe; from there it went with the colonist to other continents. The vegetable migrations following, as it were, spontaneously in the wake of man, are as many agencies in increasing the vegetable stock of a new country; but they will fall short of the vast auxiliary which can be offered to youthful nature by the thinking mind of man, when he takes the light of science as a guide to investigate the true wants of the country, and directs her energy in conformity with the organic laws of nature.

Opportunity for the Introduction of New Plant Life.

This, my friends, let us endeavor to make our great aim on these virgin islands, where we have met together from so many parts of the world to be formed into a homogeneous community. Rare advantages accrue to us from the various combinations of elements of which our rising state recruits itself. The matured experience and knowledge of many nations is centered in your society. You are situated on the central station of important commercial lines and have direct communication with four continents and many island groups. The great variety of your climate permits you to appropriate to yourselves most productions of warm and temperate zones. Insufficiency of perennial vegetation is the only true cause which renders our Islands so far inferior in their resources to the islands of the East and West Indies. Take a survey of the different districts of our group. Those you will find the most productive which are in the neighborhood of, or surrounded by wooded mountains, as Hilo and Kona in Hawaii, and Hanalei in Kauai. Go to work then to fill up the lacunas left yet by nature. Cover the dreary dark of our naked hills with the fresh verdure of shrub and

tree. Intermingle the lofty pine and cedar with the graceful acacia, the stately eucalyptus, the broad shaded tamarind and ceiba! Between them rear the towering teak tree of India, and the gigantic sequoia of California, to yield in times to come the solid timber for your nascent shipping. The dark foliage of the orange and citron, serving as foil to their golden fruit, must cluster round the cool moss-inlaid springs, which will soon bubble forth as if struck by Moses' rod, from every nook and corner between rocks, and under the fern tree, to unite in rivulets and streams which, encased in a framework of bamboo cane and lianes, will pour out of every valley, and cover with fertility the now arid and sterile plains. Then these will swell, as if Pandora's horn were emptied over them, with the turgid cane, the fragrant coffee, the speckled cotton and broad-leaved cacao, while here and there a copse of wood and shrubbery will offer shelter and food to those lovely songsters whom you are so anxious to admit into your society, but who certainly will shun it unless you build them convenient houses, and plant them food of their liking. Thus your Islands, looming over the distant horizon, encircled with a columnar row of massive cocoas, graceful arecas and stately coryphaenas, will indeed appear to the approaching stranger like a cluster of gems in the wide ocean, bidding fair to realize the fanciful dreams of his youth.

Lack of Conservation of Trees Already in Hawaii.

But before all, let us not neglect the vegetable treasures already accumulated by Nature's own unaided efforts. But here we are suddenly arrested in our fanciful excursion by a sad reflection. Have we really only the grateful task to assist nature, to rear into vigorous manhood the tender child intrusted to our care? Alas! our civilization only dates of yesterday, and already nature bleeds from many wounds inflicted by the cupidity and reckless selfishness of man. Where are the forests of sandal trees, which used to shed a halo of fragrance around the mere name of the Hawaiian Islands? A vast source of wealth has been dried up, a rich mine of gold—whose yield ought to have increased from year to year—has been squandered away, perhaps never to be worked again; for what little there is left of it, mostly crippled shoots of old trunks, bids fair with its slow growth to be stifled and crowded out by meaner, more precocious neighbors. Another source of wealth, whose importance will only be appreciated when our neighbors of California and Oregon have made sufficient progress in industry to be able to dispense with imported furniture, exists in the koa tree, *Acac. heterophylla.* Its many fine qualities for cabinet work make it equal to mahogany; in durability of color it excels the same. If we go on to fell these trees without proportioning the increase to the consumption, this source of wealth is likewise doomed to extinction—a fate which has already befallen the splendid tamani, *Calophyllum inophyllum,* of which only a few relics exist on Molokai. Has any one of you met with a fresh plantation of cocoa palms? How is it that, for instance, here on Oahu the magnificent and productive bread-fruit tree is so little cultivated? Is there a tree more picturesque to the eye, offering at the same time a liberal shade and a most nutritious, pleasant fruit? In the valley of Hanalei grows a tree (of the genus *Xanthoxylum*) called by the natives mokihana, whose seeds, seed-capsules, and leaves are impregnated with a spicy aroma similar to cardamon, but sharper to the taste. It is, to my knowledge, not found in any

This tree is a remnant of the sandalwood forests to which Dr. Hillebrand makes reference. Photographed on an Oahu ranch, December, 1919.

other locality, and to all appearance is indigenous. Unless taken care of, it may be lost, sooner or later, whereas, if propagated and protected, it is likely to become an important addition to the number of known spices, and a valuable article of export.

Encroachment on the Original Forest of Waimea Plains.

It cannot be denied, that in many places the domain of forest has been seriously encroached upon by man, and more by cattle. In the February number of the Sandwich Islands Magazine, an intelligent observer calls our attention to the startling fact that the whole plateau of Waimea, in Hawaii, over twenty miles in length and five in breadth, has been spoliated entirely of its original forest, which only twenty-five years ago formed an impenetrable thicket, by the agency of wild cattle; not a tree or shrub is to be seen now from Kawaihae to

the opposite sea-shore. Mark the effect: for the last nine months, as I am informed, they have not had a rain shower. The extended plain, which, after having been divested of its trees, probably was supposed to yield abundance of pasture to flocks and herds, is parched and cracked; not a blade of fresh grass is to be seen; clouds of dust have taken the place of rain-clouds, and the cattle, to escape starving, have to repair to the side valleys of the Kohala range and Mauna Kea. Do not object to me, that we have had an unusually dry year over the whole group, for I have yet to learn that any other region as elevated as Waimea, 4000 feet above the level of the sea, which has retained its native foliage, has been visited by a similar drought. It is alleged that the climate has improved since this process of destruction was carried on. It is true, raw mists and chilly winds are not so frequent there now, and the squally mumuku has ceased to blow, but perhaps the latter might have been averted, not by killing the vegetation on the high plains of Waimea, but by starting a new one on the slope of Kawaihae, which would have reduced the excess of heat peculiar to that desolate lava region. Besides, it may be necessary to remark here, that salubriousness and productiveness of a country do seldom go hand in hand. For, taking as a measure for general salubrity, the average percentage of deaths by consumption, we find that the healthiest spots until now ascertained are neither Rome, nor Madeira, nor the Provence, but the rainless coast of Malaga in Spain, those parts of Egypt above the Delta, nearest the desert, and, before all, Algiers, where, according to Drs. Haspel and Jourdain, only one death in seventy-five is due to consumption, while in Paris and London the proportion stands one to five.

Disastrous Effects of Cattle and Sheep on Vegetation.

During my short stay in Australia I had ample opportunity to notice the disastrous effects of cattle and sheep on vegetation. In South Australia, for instance, the original flora has almost disappeared on the rich plain between the sea and coast range. Even the formerly impenetrable thicket of the scrub along the river Murray, begins to feel its effect. Perhaps that country, which, almost shadeless on account of the perpendicular inclination of the plane of its foliage, whose tough, leathery qualities almost unfit it for a copious perspiration, lacks of rain for eight months in succession, will in distant future have to regret that its early colonists began their work of civilization with flocks and herds. Of all the destoying influences man brings to bear on nature, cattle is the worst. In what are now the Kirgisian steppes, between the Altai and Ural mountains, Humboldt found a remarkable succession of lakes, from whose relative positions to each other, in combination with the geographical formation of the country, he concluded that they formerly had been united in one sheet of water, which covered the vast plain. The great traveler does not refer to great phyiical revolutions which might have opened an outlet to these accumulated waters, but from more direct observation made in the neighboring steppe of Bareaba, he is led to believe that the presence of man has to account for it. A retrospect in history, however, shows us that this is part of the very country where lived the Scythians, from where issued the Huns, Mongols and Turks, all nomadizing tribes, which to our knowledge had only a faint acquaintance with agri-

culture. Herds of cattle and horses were their sustenance, formed their wealth. Is it not legitimate, therefore, to ascribe to them this great change in the physical physiognomy of this country?

Let us take a warning from such ominous examples. The small area of our Islands is too valuable to be devoted to cattle rearing. Allow them to multiply for all the legitimate purposes of the dairy, home consumption and supply to the shipping. But what goes beyond is of evil. If we rear them for the sake of their hides and tallow, I imagine the expense of producing these is too great. We forfeit by it the vital sources of our soil. It is even questionable if by fostering an export of cured or dried meat we promote our true interests. The multiplication not only, but the existence of wild cattle and goats ought to be set a stop to. Where the interests of agriculture and cattle-rearing conflict, the former should be protected in preference.

Demand for Fuel from Our Forests.

I have not touched yet upon the other evil, arising from the destruction of forests—scarcity of fuel. A few remarks will suffice. In our community this evil is already felt severely at the present time; the high price of fuel attests it. What we consume in Honolulu has for the greatest part to be brought from other islands. And yet we can never flatter ourselves with the hope to find relief in that great resource which unexpectedly came to help other countries over their impending difficulty—fossil coal. For, adopt either of the two propounded theories about the geological history of our Islands, you will arrive at the same result. If you adhere to the hypothesis of a late rising above the surface of the sea, this must have taken place in the latest epoch of the consolidation of our earth's crust; for only coral limestone, with detritus and conglomerations of the basaltic rock, cover the lower surface of our basaltic hills; no rocks of the transition or secondary groups which furnish the beds for fossil coal are seen anywhere. Do you attribute an older age to an Hawaiian, or if you will stretch your imagination a little farther, a Pacific continent, which by gradual subsidence has left the peaks of its highest ranges as our present archipelago, then those plains and estuaries, where ancient vegetation either grew or became accumulated by the rush of waters, must lie now submerged deep beneath the rolling swell of the ocean. Thus our only resource will have to be found in our forests. A little further reflection on our part must still more forcibly impress us with the importance of the subject. The number of species of trees as are well adapted to produce heat for economical purposes, is very limited. The prevailing character of our forests is that of bush and shrub; most of the taller trees are of so light a texture as to be unfit for heating. How does it stand with the fuel trees mostly in use? The ohia lehua (*Metrosideros polymorpha*) has probably in former times been the most prevailing tree over the group. It is not now. I have seen only few scattering rudiments of it, where there are unmistakable indications that formerly it covered extensive dimensions of ground. But the demand for fuel must necessarily grow in proportion to the increase of population and the concomitant necessary establishment of workshops and factories. I do not wish to be understood as favoring the introduction of manufactures at large in our fair Islands; on the contrary,

I most heartily deprecate such an idea; besides, I consider its realization impossible. But there are certain branches of industry a well-organized community cannot dispense with. These are either such as enter into the primary necessities of daily life, but cannot on account of undue bulk be shipped without raising the price quite beyond proportion, or such as can be produced with small labor on the spot where the raw material is raised. To confine myself only to one example. We build our houses of the very material least suited to a warm climate, of wood. Not only does it oblige us to live, or rather to swelter, in an atmosphere often heated almost to the temperature of blood, but it exposes our fast filling villages before long to a great and inevitable calamity. Coral rock, the only other material on hand, commands, on account of the great labor its cutting requires, such a price as to be only within the reach of very few. Besides, it could only be used to advantage for larger buildings. The only good building material which ought to be general amongst us, and at the reach of every one, is bricks. Transport from the United States raises their price to six or eight times their original value. Good raw material is in abundance amongst us; the alluvium on the banks of the river and the deposit in old taro patches chiefly consists of a very stiff clay, the common product of disintegration of basaltic rocks. On the banks of rivers it may be obtained, almost pure, unmixed. On inquiry why no bricks were made here, I have been told that attempts had been made, but the high price of fuel obliged the undertaker to abandon the enterprise as unprofitable. Part of the preceding remarks will also refer to pottery. With regard to this branch of industry it may be of use to record that in Teneriffe, in order to obtain the clay of which those valuable porous water jars, *gargolettas,* are made, the natives build retaining walls at the foot of the mountains, to collect the water which deposits this precious detritus of their trachytic rocks.

The Protection of Forests Against Wind.

Before I conclude, I cannot but refer briefly to the shelter well-established forests will afford against high wind, by common consent one of the greatest impediments to the successful pursuit of agriculture and horticulture with us. Forests, located with a special regard to the prevailing wind, would be highly beneficial to circumscribed localities. But allow me in this place to advance a hypothesis, according to which, if it should prove correct, the influence of forests in modifying the strength and current of winds, would be of more general application. Honolulu with its environs offers a good example for illustration. The ordinary trades that strike over the plain of Koolaupoko, on the windward side, are broken by the abrupt circular range of mountains which include it like an amphitheatre. Their only outlet of this great *cul de sac,* is the deep notch over the Pali of Nuuanu, elevated eight hundred feet above the sea, into which they crowd with concentrated strength. One should suppose that the lower currents, which swept over the plains of Koolau at a less elevation than eight hundred feet, would, in passing the Pali, assume an upward direction, while the upper ones would continue a horizontal course. Such being the case, they ought to pass at least eight hundred feet over our heads, while in reality, as soon as they have traversed the Pali, they take a downward course

and sweep over the surface of Nuuanu Valley down on Honolulu. As a general rule our nights and mornings are calm; the trades appear in Honolulu about ten o'clock in the morning, and last to five or six o'clock in the afternoon; that is, just as long as the sun's heat rarefies the atmosphere over the lower part of Nuuanu and the plain. If my recollection serves me right, the wooded part of the valley nearest the Pali is generally calmer than any other part of it; the traveler in approaching the Pali, receives the violent gust of wind quite suddenly when immediately near it. May it not reasonably be supposed, that if we lessen the rarefication of the atmosphere in the lower valley and on the plain, by cooling it down through the presence of trees, we can succeed in giving to the ordinary trades a less downward inclination, to raise it, if not eight hundred feet, at least some fifty or sixty feet over our heads? We should still have breeze enough to make us feel comfortable, but our trees would not shed their fruit, and there would be a great deal less of rheumatism in our village. Many other parts of the leeward side of our Islands are similarly situated to Honolulu.

Necessity for Action in the Planting and Importation of Seeds.

It remains for me only to make a few remarks on the practicability of a plan of such extent, as the one propounded undoubtedly is. Of course it cannot be accomplished in one year, or a couple of years. In northern latitudes the raising of a new forest, even of fast-growing trees, will take from fifteen to thirty years. Here our patience will not have to be put to such a stretch. Where, as I had occasion to observe in my garden, some species of Acacia will grow in little more than one year to the height of twenty-four feet, from the seed, Melias sixteen feet, and Casuarinas ten feet, there it may be admissible to feel somewhat sanguine on the subject. It is my opinion that on the banks of rivers and in low wet places our end may be attained in less than four years. In dry, unsheltered plains, bare hills or elevated districts, it may take longer time. Nowhere, I imagine, we shall have to wait more than six or eight years before some results are obtained. The work cannot be done by a few individuals; the whole nation must lay hand on this great national work. And if it were for no other reason than this, I hail with joy this festival occasion which for the first time has assembled our native friends of the National Hawaiian Agricultural Society with us. The same idea has called their society into life, as ours; the same zeal animates them to realize it, to embellish and enrich the fair land of their inheritance. Let every member of our societies enter an engagement to plant yearly a certain number of trees; let our society import seeds from abroad in quantities for distribution, particularly of such trees as are of some economical use; but let us make an immediate beginning with the vegetable treasures, native or domiciliated on our soil. To prevent failures from error in judgment, Government may designate competent persons whose duty it shall be to select and assign places where a beginning may be made with the best advantage, and appoint wardens for the protection of the young plantations. Indeed, amongst all the monuments a wise and great ruler may erect himself for posterity, which are more beautiful and durable than those that will shed blessing and happiness on his nation's children and grandchildren? Which are greater than those which comprise at once every one of his subjects and every

square foot of his kingdom? Which more admirable than such as founded by an enlightened sagacity, penetrating the hidden future, tend at once to avert unseen calamities and secure unhoped for happiness? Works of this character, not their wars, secure to the name of Henry IV, Peter and Frederick the Great, a grateful abode on the lips of the humblest peasant of their nations. Thus amongst the claims on posterity's gratitude, the great Akbar founded himself in India; one, not the smallest, consists in his directing "to plant trees of every description on both sides of the canal down to Hissar, both for shade and blossom, so as to make it like the canal under the trees in Paradise, and that the sweet flavor of the rare fruits may reach the mouth of every one, and that from those luxuries a voice might go forth to travelers, calling them to rest in the cities, where their every want will be supplied."